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# Watershed Impacts of Recreational Development in the Guadalupe Mountains National Park, Texas

Texas Tech Univ.
Lubbock

Prepared for

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E. B. Fish, M. J. Dvoracek, V. B. Ackerson, B. L. Allen, and G. L. Brothers.

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In the southwestern United States, there is widespread concern about the hydrologic effects of a rapidly increasing population and the consequent drastic changes in the types and intensity of land use. This research effort was directed towards obtaining a data base consisting of climatic, vegetative, soil, erosional and hydrologic information which would be useful in the management decision making process for Guadalupe Mountains National Park, Texas. Based on initial studies five watersheds ranging in size from 25.32 square miles to 0.15 square miles were selected for intensive studies to quantify relationships between soil, vegetation, climatic, topographic, and geologic factors in such a way that they may be used as a basis for predicting the effects of modification in land use on erosion, water yield and quality, flooding and ground water supplies.

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In the southwestern United States, there is widespread concern about the hydrologic effects of a rapidly increasing population and the consequent drastic changes in the types and intensity of land use. This research effort was directed towards obtaining a data base consisting of climatic, vegetative, soil, erosional and hydrologic information which would be useful in the management decision making process for Guadalupe Mountains National Park, Texas. Based on initial studies five watersheds ranging in size from 25.32 square miles to 0.15 square miles were selected for intensive studies to quantify relationships between soil, vegetation, climatic, topographic, and geologic factors in such a way that they may be used as a basis for predicting the effects of modification in land use on erosion, water yield and quality, flooding and ground water supplies. Recommendations resulting from this project include: development of programs to establish appropriate recreational carrying capacities based on biophysical impacts on resource systems as well as sociological carrying capacity aspects; consideration of the highly erodible nature of most soils found in the park in the design criteria for trails and other facilities; continued monitoring of erosion transects on current roads and trails to further evaluate the erosion potential of soils found in the park; continued monitoring of water quality parameters with special emphasis on the McKittrick Canyon stream in the vicinity of the Pratt Lodge cesspool; development of plans for an improved waste disposal system in South McKittrick Canyon; continued monitoring of surface runoff phenomena and characteristics to refine predictions & establish explicit relationships for runoff phenomena.

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# WATERSHED IMPACTS OF RECREATIONAL DEVELOPMENT IN THE GUADALUPE MOUNTAINS NATIONAL PARK, TEXAS

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E. B. Fish

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# TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS . . . . . . . . . . . . . . . . . . . . . . . . ii

LIST OF TABLES . . . . . . . . . . . . . . . . . . . . . . . . . x

LIST OF FIGURES . . . . . . . . . . . . . . . . . . . . . . . xviii

CHAPTER I INTRODUCTION . . . . . . . . . . . . . . . . . . . . 1

- RELEVANCE OF RESEARCH . . . . . . . . . . . . . . . . . . . 1
- OBJECTIVES . . . . . . . . . . . . . . . . . . . . . . . . 3
- STUDY LOCATION . . . . . . . . . . . . . . . . . . . . . . 4
- REPORT FORMAT . . . . . . . . . . . . . . . . . . . . . . . 8

CHAPTER II HISTORY OF MAN'S IMPACT ON GUADALUPE MOUNTAINS NATIONAL PARK . . . . . . . . . . . . . . . . . . . . . . 9

- PREHISTORIC AND HISTORIC ACTIVITIES . . . . . . . . . . . . 9
- RECENT ACTIVITIES . . . . . . . . . . . . . . . . . . . . . 19

CHAPTER III WATERSHED INVENTORY STUDIES . . . . . . . . . . . . 26

- DATA COLLECTION . . . . . . . . . . . . . . . . . . . . . . 27
  - AREAL EXTENT . . . . . . . . . . . . . . . . . . . . . . 27
  - SHAPE COEFFICIENTS . . . . . . . . . . . . . . . . . . . 28
  - BASIN PERIMETER . . . . . . . . . . . . . . . . . . . . . 29
  - DRAINAGE NETWORK . . . . . . . . . . . . . . . . . . . . 29
  - CHANNEL PROFILES . . . . . . . . . . . . . . . . . . . . 30
  - MAJOR VEGETATIVE COMMUNITIES . . . . . . . . . . . . . . 31
  - MAJOR GEOLOGIC PARENT MATERIALS . . . . . . . . . . . . . 31
  - LAND FORM . . . . . . . . . . . . . . . . . . . . . . . . 32
- DATA ANALYSIS . . . . . . . . . . . . . . . . . . . . . . . 32
- RESULTS AND DISCUSSION . . . . . . . . . . . . . . . . . . . 32

CHAPTER IV GEOLOGIC CONSIDERATIONS . . . . . . . . . . . . . . 43

- INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . 43
- INTENSIVE STUDY AREA . . . . . . . . . . . . . . . . . . . . 51

CHAPTER V CLIMATOLOGY . . . . . . . . . . . . . . . . . . . . . 61

- INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . 61

INSTRUMENTATION . . . 63
RESULTS . . . 67
  STATION WS-1 . . . 67
  STATION 8B-8D . . . 67
  STATION WS-6 . . . 72
  STATION 10A6 . . . 80
  STATION BOWL . . . 80
ANALYSIS . . . 84

CHAPTER VI VEGETATION . . . 91
WATERSHED 1 . . . 93
  DRY, VERY STONY SLOPE (50%)--SITE . . . 93
  HEAVILY OAKEN SLOPE (49%)--SITE . . . 108
  DRY, OAKEN, STONY SLOPE (46%)--SITE . . . 108
  DRY, STONY SLOPE (58%)--SITE . . . 116
  OPEN RIDGETOP--SITE . . . 120
  DRY, ROCKY SLOPE (21%)--SITE . . . 130
  VALLEY FLOOR--SITE . . . 130
  MEADOW--SITE . . . 132
  ESCARPMENT--SITE . . . 135
  WOODED RIDGETOP--SITE . . . 141
  STEEP WOODED SLOPE (49%)--SITE . . . 150
  STEEP INTERMEDIATELY WOODED SLOPE (50%)--SITE . . . 157
  STEEP WOODED NORTHEASTERN SLOPE (41%)--SITE . . . 160
  DENSELY WOODED RIDGETOP--SITE . . . 163
WATERSHED 10A6 . . . 163
  PX RIDGE--SITE . . . 165
  PX FLAT--SITE . . . 176
  CREOSOTE--SITE . . . 182
  OUTCROP--SITE . . . 185
  GYPSUM--SITE . . . 194
  CHANNEL--SITE . . . 194
WATERSHED 8B-8D . . . 199
  SHRUB-GRASSLAND--SITE . . . 199
  NORTH SLOPE SHRUBLAND--SITE . . . 205
  GRASSLAND RIDGE--SITE . . . 207

GRASSLAND MEADOW--SITE 210
WATERSHED 7 210
STEEP OPEN--SITE 210
HIGHER ELEVATION RIDGETOP (5900 ft.)--SITE 217
MID-ELEVATION RIDGETOP (5440 ft.)--SITE 220
LOWEST ELEVATION RIDGE (5270 ft.)--SITE 222
STEEP SOUTHERN RIDGE--SITE 224
STEEP NORTHEASTERN RIDGE--SITE 227
SHRUB SLOPE BENCH--SITE 229
GRASSLAND BENCH--SITE 233
WATERSHED 6 236
STEEP WOODED SLOPE (49%)--SITE 242
STEEP INTERMEDIATELY WOODED SLOPE (50%)--SITE 244
WOODED RIDGETOP--SITE 245
DRY, STONY SLOPE (58%)--SITE 245
BOWL--SITE 246
ROCKY, LOWER SLOPE (5800 ft.)--SITE 246
STEEP OPEN--SITE 250
CREEK BOTTOM--SITE 256

CHAPTER VII SOIL CONSIDERATIONS 260
INTRODUCTION 260
SOIL SURVEY 261
DESCRIPTIONS OF MAPPING UNITS 272
CRB Cuevoland Variant-Ruidoso-Deama Complex (1-8% Slopes) 272
CND Canutio-Nickel Complex (3-20% Slopes) 272
DRD Deama-Rock Outcrop-Flume Complex (5-20% Slopes) 273
DRF Deama-Rock Outcrop-Flume Complex (20-50% Slopes) 274
DRG Deama-Rock Outcrop Complex (40-50% Slopes) 274
ECF Ector-Rock Outcrop Complex (20-50% Slopes) 275
ERD Ector-Rock Outcrop-Flume Complex (5-30% Slopes) 275
ERF Ector-Rock Outcrop-Flume Complex (20-50% Slopes) 276
FDD Flume-Rock Outcrop-Deama Complex (5-30% Slopes) 277
FDF Flume-Rock Outcrop-Deama Complex (20-50% Slopes) 278
FRD Flume-Rock Outcrop Complex (5-30% Slopes) 278

FRF Flume-Rock Outcrop Complex (20-50% Slopes) . . . . . 279
HCD Holloman-Canutio-Nickel Complex (3-15% Slopes) . . . 279
LOD Lozier-Rock Outcrop Complex (5-30% Slopes) . . . . . 280
LOF Lozier-Rock Outcrop Complex (20-50% Slopes) . . . . 281
LRD Lozier-Rock Outcrop-Holloman Variant Complex (5-30% Slopes) . . . . . . . . . . . . . . . . . . . . . . . 281
MIB Mibres-Torrifluvents Complex (0-3% Slopes) . . . . . 282
NCB Nickel-Canutio Complex (1-5% Slopes) . . . . . . . . 283
NCD Nickel-Canutio Complex (5-20% Slopes) . . . . . . . 283
ORD Sombordoro-Rock Outcrop Complex (5-30% Slopes) . . . 284
PAB Penasco Soils (0-3% Slopes). . . . . . . . . . . . . 284
PCB Pajarito-Canutio Complex (1-5% Slopes) . . . . . . . 285
PIB Pajarito-Bluepoint Complex (1-5% Slopes) . . . . . . 285
PND Pena-Penasco Complex (5-20% Slopes) . . . . . . . . 286
PPB Pena-Penasco-Fluventic Haplustolls Association (0-3% Slopes) . . . . . . . . . . . . . . . . . . . . 286
RPG Rock Outcrop-Deama Complex (40-50% Slopes) . . . . . 287
RRB Remunda-Ruidoso-Pena Complex (0-5% Slopes) . . . . . 288
TRD Travessilla-Rock Outcrop Complex (5-30% Slopes) . . 289
EFFECTS OF ASPECT AND ELEVATION . . . . . . . . . . . . . . 289
PREVIOUS WORK . . . . . . . . . . . . . . . . . . . . . 289
Effect of Aspect and Elevation on Soil Temperature . . . 289
Effects of Soil Temperature, as Influenced by Aspect, on Soil Properties . . . . . . . . . . . . . . . . . . 292
Morphological Properties . . . . . . . . . . . . . . 292
Physical Properties . . . . . . . . . . . . . . . . . 293
Chemical Properties . . . . . . . . . . . . . . . . . 294
Mineralogical Properties . . . . . . . . . . . . . . 295
MATERIALS AND METHODS . . . . . . . . . . . . . . . . . 295
Soil Sampling . . . . . . . . . . . . . . . . . . . . . 296
Temperature Cell Installation and Measurements . . . . . 296
Particle Size Distribution . . . . . . . . . . . . . . . 302
Soil Reaction . . . . . . . . . . . . . . . . . . . . . 302
Electrical Conductivity . . . . . . . . . . . . . . . . 302
Soluble Cations . . . . . . . . . . . . . . . . . . . . 302
Cation Exchange Capacity . . . . . . . . . . . . . . . . 303

Organic Carbon . . . . . . . . . . . . . . . . . . . . . . . . 303
Ammonium Acetate Extractable Cations . . . . . . . . . . . 304
Water Saturation Percentage . . . . . . . . . . . . . . . . 304
Water Retention . . . . . . . . . . . . . . . . . . . . . . 304
Coarse Fragment Procedures . . . . . . . . . . . . . . . . . 304
Calcium Carbonate . . . . . . . . . . . . . . . . . . . . . 305
Qualitative Gypsum Test . . . . . . . . . . . . . . . . . . 305
Clay Separation for X-ray Analysis . . . . . . . . . . . . 305
X-Ray Diffraction of Clays . . . . . . . . . . . . . . . . . 306
DISCUSSION OF RESULTS . . . . . . . . . . . . . . . . . . . . 307
CONCLUSIONS . . . . . . . . . . . . . . . . . . . . . . . . . 331

CHAPTER VIII WATER QUALITY . . . . . . . . . . . . . . . . . . 332
INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . . . 332
HISTORY OF WATER USE IN THE PARK . . . . . . . . . . . . . . 333
PREVIOUS WORK . . . . . . . . . . . . . . . . . . . . . . . . 336
METHODS . . . . . . . . . . . . . . . . . . . . . . . . . . . 341
SAMPLE SITE SELECTION . . . . . . . . . . . . . . . . . . . . 341
WATER QUALITY PARAMETERS . . . . . . . . . . . . . . . . . . 357
RESULTS AND DISCUSSION . . . . . . . . . . . . . . . . . . . . 361
SPRINGS . . . . . . . . . . . . . . . . . . . . . . . . . . . 361
McKITTRICK CANYON STREAM . . . . . . . . . . . . . . . . . . 363
CONCLUSIONS . . . . . . . . . . . . . . . . . . . . . . . . . 366

CHAPTER IX SURFACE HYDROLOGY AND EROSION . . . . . . . . . . . 368
INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . . . 368
FIELD SURVEYS . . . . . . . . . . . . . . . . . . . . . . . . 369
DETERMINATION OF RUNOFF . . . . . . . . . . . . . . . . . . . 378
ESTIMATION OF PEAK RUNOFF . . . . . . . . . . . . . . . . . . 382
RATIONAL METHOD . . . . . . . . . . . . . . . . . . . . . . . 382
SOIL CONSERVATION METHOD . . . . . . . . . . . . . . . . . . 386
COMPARISON OF METHODS . . . . . . . . . . . . . . . . . . . . 394
EROSION TRANSECTS . . . . . . . . . . . . . . . . . . . . . . 405

CHAPTER X LANDSCAPE UNIT ANALYSIS . . . . . . . . . . . . . . 409
PREVIOUS WORK . . . . . . . . . . . . . . . . . . . . . . . . 410
DATA COLLECTION . . . . . . . . . . . . . . . . . . . . . . . 425

BOUNDARY TEST . . . . . . . . . . . . . . . . . . . . . . . . 429
SIMILARITY TESTS . . . . . . . . . . . . . . . . . . . . . . 435
HOMOGENEITY TESTS . . . . . . . . . . . . . . . . . . . . . . 437
RESULTS AND DISCUSSION . . . . . . . . . . . . . . . . . . . . 439
CONCLUSIONS . . . . . . . . . . . . . . . . . . . . . . . . 451
CHAPTER XI RECOMMENDATIONS . . . . . . . . . . . . . . . . . . . 459
LITERATURE REVIEWED . . . . . . . . . . . . . . . . . . . . . . 464
APPENDICIES (A -- O)

# LIST OF TABLES

| Table | | Page |
|---|---|---|
| 1. | TRAIL USER DAYS AND OVERNIGHT STAYS FOR GUADALUPE MOUNTAINS NATIONAL PARK | 22 |
| 2. | HYDROLOGIC CHARACTERISTICS OF WATERSHEDS | 35 |
| 3. | MILES OF CHANNEL LENGTH BY STREAM ORDER | 36 |
| 4. | PERCENT COMPOSITION BY VEGETATIVE COMMUNITIES | 38 |
| 5. | PERCENT COMPOSITION BY GEOLOGIC PARENT MATERIALS | 39 |
| 6. | PERCENT COMPOSITION BY SLOPE GRADIENTS | 40 |
| 7. | MOST SIMILAR WATERSHED PAIRS BY HYDROLOGIC VARIABLES | 41 |
| 8. | SURFICIAL GEOLOGY COMPOSITION WATERSHED 1 | 52 |
| 9. | SURFICIAL GEOLOGY COMPOSITION WATERSHED 10A6 | 52 |
| 10. | SURFICIAL GEOLOGY COMPOSITION WATERSHED 8B | 53 |
| 11. | SURFICIAL GEOLOGY COMPOSITION WATERSHED 8D | 53 |
| 12. | SURFICIAL GEOLOGY COMPOSITION WATERSHED 7 | 54 |
| 13. | SURFICIAL GEOLOGY COMPOSITION WATERSHED 6 | 54 |
| 14. | PRECIPITATION INTENSITY SUMMARY STATION WS-1 | 69 |
| 15. | PRECIPITATION INTENSITY SUMMARY STATION 8B-8D | 69 |
| 16. | PRECIPITATION INTENSITY SUMMARY STATION WS-6 | 77 |
| 17. | PRECIPITATION INTENSITY SUMMARY STATION 10A6 | 83 |
| 18. | PRECIPITATION INTENSITY SUMMARY STATION BOWL | 83 |
| 19. | CORRELATION COEFFICIENTS AND PROBABILITY $>\|R\|$ UNDER Ho :: R = 0; N = 24 | 86 |
| 20. | SELECTED REGRESSION MODELS FOR PRECIPITATION STATIONS WITHIN THE PARK. $\hat{Y} = a + bx$ (N = 24) | 86 |
| 21. | CORRELATION COEFFICIENTS AND PROBABILITY $>\|R\|$ UNDER Ho :: R = 0; N = 23 | 89 |
| 22. | SELECTED REGRESSION MODELS FOR PRECIPITATION STATIONS WITHIN THE PARK. $\hat{Y} = a + bx$ (N = 23) | 89 |
| 23. | SELECTED REGRESSION MODELS FOR PRECIPITATION STATIONS INSIDE AND OUTSIDE THE PARK. $\hat{Y} = a + bx$ | 90 |
| 24. | SITES AND COMMUNITIES OF WATERSHED 1 | 94 |
| 25. | VEGETATIVE COMPOSITION WATERSHED 1 | 96 |
| 26. | SITE CHARACTERISTICS OF THE DRY, VERY STONY SLOPE (50%) SITE | 98 |

## LIST OF TABLES (continued)

Table Page

27. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE TYPICAL EXPRESSION OF THE SMALLSEED SACAHUISTA-BLUE THREEAWN-SIDEOATS GRAMA COMMUNITY 101

28. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-SIDEOATS GRAMA COMMUNITY 103

29. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-NEW MEXICO MUHLY-LITTLEAWN NEEDLEGRASS-SIDEOATS GRAMA COMMUNITY 104

30. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-NEW MEXICO MUHLY COMMUNITY 106

31. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE DESERT ROSE-NEW MEXICO MUHLY-PINE MUHLY COMMUNITY 107

32. SITE CHARACTERISTICS OF THE HEAVILY OAKEN SLOPE (49%) SITE AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-NEW MEXICO MUHLY COMMUNITY 109

33. SITE CHARACTERISTICS OF DRY, OAKEN, STONY SLOPE (46%) SITE 112

34. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMALLSEED SACAHUISTA-SIDEOATS GRAMA-BLUE THREEAWN COMMUNITY 114

35. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMALLSEED SACAHUISTA-NEW MEXICO MUHLY-SIDEOATS GRAMA COMMUNITY (COMPOSITE DATA OF THE VARIATIONS MENTIONED IN TEXT) 115

36. SITE CHARACTERISTICS OF THE DRY, STONY SLOPE (58%) SITE AND SPECIES COMPOSITION OF THE MOUNTAIN MAHOGANY-WAVYLEAF OAK-NEW MEXICO MUHLY COMMUNITY 117

37. SITE CHARACTERISTICS OF THE OPEN RIDGETOP SITE AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-MOUNTAIN MAHOGANY-PLAINS LOVEGRASS-NEW MEXICO FEATHERGRASS COMMUNITY 121

38. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PINYON PINE-FINESTEM NEEDLEGRASS COMMUNITY (INCLUSION) 124

39. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-PLAINS LOVEGRASS COMMUNITY (INCLUSION) 127

40. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PONDEROSA PINE-NEW MEXICO MUHLY-LITTLEAWN NEEDLEGRASS COMMUNITY (INCLUSION) 129

## LIST OF TABLES (continued)

| Table | | Page |
|---|---|---|
| 41. | SITE CHARACTERISTICS OF THE DRY, ROCKY SLOPE (21%) SITE AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-MOUNTAIN MAHOGANY-PINE MUHLY-PLAINS LOVEGRASS COMMUNITY | 131 |
| 42. | SITE CHARACTERISTICS OF THE VALLEY FLOOR SITE AND SPECIES COMPOSITION OF THE ALLIGATOR JUNIPER-GRAY OAK-SIDEOATS GRAMA COMMUNITY | 133 |
| 43. | SITE CHARACTERISTICS OF THE MEADOW SITE AND SPECIES COMPOSITION OF THE FINESTEM NEEDLEGRASS COMMUNITY | 134 |
| 44. | SITE CHARACTERISTICS OF THE ESCARPMENT SITE | 136 |
| 45. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-PINE MUHLY COMMUNITY | 138 |
| 46. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMALLSEED SACAHUISTA-PINE MUHLY-BULL MUHLY COMMUNITY | 139 |
| 47. | SITE CHARACTERISTICS OF THE WOODED RIDGETOP SITE | 142 |
| 48. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PONDEROSA PINE-ALLIGATOR JUNIPER-PINE MUHLY COMMUNITY COMPLEX | 143 |
| 49. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-MOUNTAIN MAHOGANY-PLAINS LOVEGRASS-PINE MUHLY COMMUNITY | 147 |
| 50. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PINYON PINE-NEW MEXICO MUHLY COMMUNITY | 149 |
| 51. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PONDEROSA PINE-WAVYLEAF OAK-CAREX COMMUNITY | 151 |
| 52. | SITE CHARACTERISTICS OF THE STEEP WOODED SLOPE (49%) SITE | 152 |
| 53. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE DOUGLAS FIR-NEW MEXICO MUHLY COMMUNITY | 154 |
| 54. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PONDEROSA PINE-WAVYLEAF OAK-NEW MEXICO MUHLY COMMUNITY | 156 |
| 55. | SITE CHARACTERISTICS OF THE STEEP INTERMEDIATELY WOODED SLOPE (50%) SITE AND SPECIES COMPOSITION OF THE ALLIGATOR JUNIPER-WAVYLEAF OAK-NEW MEXICO MUHLY-PINE MUHLY COMMUNITY | 158 |
| 56. | SITE CHARACTERISTICS OF THE STEEP WOODED NORTHEASTERN SLOPE (41%) SITE AND SPECIES COMPOSITION OF THE PONDEROSA PINE-QUERCUS-NEW MEXICO MUHLY COMMUNITY | 162 |

# LIST OF TABLES (continued)

Table Page

57. SITE CHARACTERISTICS OF THE DENSELY WOODED RIDGETOP SITE AND SPECIES COMPOSITION OF THE SOUTHWESTERN WHITE PINE-ALLIGATOR JUNIPER-PRINGLE NEEDLEGRASS COMMUNITY 164

58. SITES AND COMMUNITIES OF WATERSHED 10A6 166

59. VEGETATIVE COMPOSITION WATERSHED 10A6 167

60. SITE CHARACTERISTICS OF THE PX RIDGE SITE 169

61. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE JAVELINA BUSH-CURLYLEAF MUHLY COMMUNITY 170

62. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-CURLYLEAF MUHLY-NEW MEXICO FEATHERGRASS COMMUNITY 172

63. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE *QUERCUS*-*CAREX*-NEW MEXICO MUHLY COMMUNITY 175

64. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE MOUNTAIN MAHOGANY-NEW MEXICO MUHLY-NEW MEXICO FEATHERGRASS COMMUNITY 177

65. SITE CHARACTERISTICS OF THE PX FLAT SITE AND SPECIES COMPOSITION OF THE ONESEEDED JUNIPER-BLUE GRAMA COMMUNITY 178

66. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE MAT MUHLY-BLUE GRAMA COMMUNITY INCLUSION IN THE PX FLAT SITE 180

67. SITE CHARACTERISTICS OF THE CREOSOTE SITE 183

68. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE CREOSOTEBUSH-*SPOROBOLUS*-BLACK GRAMA COMMUNITY 184

69. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE RANGE RATANY-SKELTON GOLDENEYE-FLUFFGRASS COMMUNITY 186

70. SITE CHARACTERISTICS OF THE OUTCROP SITE 188

71. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SKELETON GOLDENEYE-GRAY COLDENIA-SLIM TRIDENS COMMUNITY 190

72. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SKELETON GOLDENEYE-SMOOTH SOTOL-WARNOCK GRAMA-SLIM TRIDENS COMMUNITY 191

73. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE CREOSOTEBUSH-PEPPERWEED-*CRYPTANTHA* COMMUNITY 193

74. SITE CHARACTERISTICS OF THE GYPSUM SITE AND SPECIES COMPOSITION OF THE RANGE RATANY-CREOSOTEBUSH-*DYSSODIA*-WOOLY INDIAN WHEAT COMMUNITY COMPLEX 195

## LIST OF TABLES (continued)

| Table | | Page |
|---|---|---|
| 75. | SITE CHARACTERISTICS OF THE CHANNEL SITE AND SPECIES COMPOSITION OF THE CREOSOTEBUSH-BLACK GRAMA COMMUNITY | 198 |
| 76. | SITES AND COMMUNITIES OF WATERSHEDS 8B AND 8D | 200 |
| 77. | VEGETATIVE COMPOSITION WATERSHED 8D | 200 |
| 78. | VEGETATIVE COMPOSITION WATERSHED 8B | 200 |
| 79. | SITE CHARACTERISTICS OF THE SHRUB-GRASSLAND SITE AND SPECIES COMPOSITION OF THE SANDPAPER OAK-REDBERRY JUNIPER-CURLYLEAF MUHLY-WARNOCK GRAMA COMMUNITY COMPLEX | 202 |
| 80. | SITE CHARACTERISTICS OF THE NORTH SLOPE SHRUBLAND SITE AND SPECIES COMPOSITION OF A PHASE OF THE SANDPAPER OAK-REDBERRY JUNIPER-CURLYLEAF MUHLY-WARNOCK GRAMA COMMUNITY COMPLEX | 206 |
| 81. | SITE CHARACTERISTICS OF THE GRASSLAND RIDGE SITE AND SPECIES COMPOSITION OF THE BLUE GRAMA-HAIRY TRIDENS COMMUNITY | 208 |
| 82. | SITE CHARACTERISTICS OF THE GRASSLAND MEADOW SITE AND SPECIES COMPOSITION OF THE BLUE GRAMA-BLACK GRAMA COMMUNITY | 211 |
| 83. | SITES AND COMMUNITIES OF WATERSHED 7 | 212 |
| 84. | VEGETATIVE COMPOSITION WATERSHED 7 | 213 |
| 85. | SITE CHARACTERISTICS OF THE STEEP OPEN SITE AND SPECIES COMPOSITION OF THE SKELETON GOLDENEYE-NEW MEXICO MUHLY-SIDEOATS GRAMA COMMUNITY | 215 |
| 86. | SITE CHARACTERISTICS OF THE HIGHER ELEVATION RIDGETOP (5900 FT.) SITE AND SPECIES COMPOSITION OF THE QUERCUS-SMOOTH SOTOL-BLUE THREEAWN COMMUNITY | 218 |
| 87. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-MOUNTAIN MAHOGANY-SIDEOATS GRAMA-LITTLEAWN NEEDLEGRASS COMMUNITY INCLUSION | 219 |
| 88. | SITE CHARACTERISTICS OF THE MID ELEVATION RIDGETOP (5440 FT.) SITE AND SPECIES COMPOSITION OF THE SMOOTH SOTOL-SIDEOATS GRAMA-BULL MUHLY COMMUNITY | 221 |
| 89. | SITE CHARACTERISTICS OF THE LOWEST ELEVATION RIDGE (5270 FT.) SITE AND SPECIES COMPOSITION OF THE LECHEGUILLA-SKELETON GOLDENEYE-CURLYLEAF MUHLY COMMUNITY | 223 |
| 90. | SITE CHARACTERISTICS OF THE STEEP SOUTHERN RIDGE SITE AND SPECIES COMPOSITION OF THE QUERCUS-SMOOTH SOTOL-SIDEOATS GRAMA-LITTLEAWN NEEDLEGRASS COMMUNITY | 225 |

## LIST OF TABLES (continued)

| Table | | Page |
|---|---|---|
| 91. | SITE CHARACTERISTICS OF THE STEEP NORTHEASTERN RIDGE SITE AND SPECIES COMPOSITION OF THE QUERCUS-SMOOTH SOTOL-MOUNTAIN MAHOGANY--LITTLEAWN NEEDLEGRASS COMMUNITY COMPLEX | 228 |
| 92. | SITE CHARACTERISTICS OF THE SHRUB SLOPE BENCH SITE | 230 |
| 93. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE GRAY OAK-SIDEOATS GRAMA-PLAINS LOVEGRASS COMMUNITY | 231 |
| 94. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE QUERCUS-REDBERRY JUNIPER-PLAINS LOVEGRASS COMMUNITY | 234 |
| 95. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE CATCLAW MIMOSA-ENGELMANN PRICKLYPEAR-BLUE GRAMA COMMUNITY | 235 |
| 96. | SITE CHARACTERISTICS OF THE GRASSLAND BENCH SITE AND SPECIES COMPOSITION OF THE REDBERRY JUNIPER-HAIRY GRAMA-BLUE GRAMA COMMUNITY | 237 |
| 97. | SITES AND COMMUNITIES OF WATERSHED 6 | 239 |
| 98. | VEGETATIVE COMPOSITION WATERSHED 6 | 240 |
| 99. | SITE CHARACTERISTICS OF THE STEEP WOODED SLOPE (48%) SITE IN WATERSHED 6 AND SPECIES COMPOSITION OF THE DOUGLAS FIR-GAMBEL OAK-NEW MEXICO MUHLY-LITTLEAWN NEEDLEGRASS COMMUNITY | 243 |
| 100. | SITE CHARACTERISTICS OF THE ROCKY, LOWER-SLOPE (5800 FT.)--SITE | 248 |
| 101. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMOOTH SOTOL-BULL MUHLY-PINE MUHLY COMMUNITY | 249 |
| 102. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMOOTH SOTOL-WAVYLEAF OAK-SIDEOATS GRAMA-BULL MUHLY COMMUNITY | 251 |
| 103. | SITE CHARACTERISTICS OF THE STEEP OPEN SITE AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMOOTH SOTOL-SIDEOATS GRAMA COMMUNITY | 253 |
| 104. | SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE BIG-TOOTH MAPLE-WAVYLEAF OAK-GREEN SPRANGLETOP COMMUNITY INCLUSION | 255 |
| 105. | SITE CHARACTERISTICS OF THE CREEK BOTTOM SITE AND SPECIES COMPOSITION OF THE REDBERRY JUNIPER-SMOOTH SOTOL-HAIRY GRAMA COMMUNITY | 257 |

## LIST OF TABLES (continued)

| Table | | Page |
|---|---|---|
| 106. | SOIL COMPOSITION WATERSHED 1 | 261 |
| 107. | SOIL COMPOSITION WATERSHED 10A6 | 264 |
| 108. | SOIL COMPOSITION WATERSHED 8B | 266 |
| 109. | SOIL COMPOSITION WATERSHED 8D | 266 |
| 110. | SOIL COMPOSITION WATERSHED 7 | 268 |
| 111. | SOIL COMPOSITION WATERSHED 6 | 268 |
| 112. | SOIL MAP LEGEND | 270 |
| 113. | CLASSIFICATION OF SOIL SERIES | 271 |
| 114. | ELEVATION AND ESTIMATED PRECIPITATION AT THE SITES STUDIED | 296 |
| 115. | SOIL TEMPERATURE MEASUREMENTS (C) AT 50 cm | 309 |
| 116. | PARTICLE SIZE DISTRIBUTION AND COARSE FRAGMENTS | 316 |
| 117. | SELECTED CHEMICAL PROPERTIES | 318 |
| 118. | WATER SOLUBLE CATIONS, WATER SATURATION PERCENTAGE, AND ELECTRICAL CONDUCTIVITY VALUES | 320 |
| 119. | WATER RETENTION VALUES AND AVAILABLE WATER | 322 |
| 120. | AMMONIUM ACETATE EXTRACTABLE CATIONS, AND PERCENTAGE BASE SATURATION | 323 |
| 121. | X-RAY DIFFRACTION SPACINGS OF SELECTED MINERALS | 329 |
| 122. | CLASSIFICATION OF SOILS | 330 |
| 123. | WATER QUALITY DATA ON WATER FROM WELLS IN GENERAL THAT WERE DRILLED IN SEDIMENTARY ROCK | 337 |
| 124. | WATER QUALITY DATA ON McKITTRICK CANYON STREAM FROM STUDIES CONDUCTED BY O. T. LIND | 342 |
| 125. | WATER QUALITY DATA ON SPRINGS FROM STUDIES CONDUCTED BY O. T. LIND IN APRIL 1971 | 343 |
| 126. | WATER QUALITY DATA ON SPRINGS FROM STUDIES CONDUCTED BY M. DICK | 344 |
| 127. | WATER QUALITY ANALYSIS PROCEDURE | 359 |
| 128. | CALCULATED PEAK DISCHARGE FROM WATERSHEDS (SLOPE-AREA METHOD) | 381 |
| 129. | RAINFALL INTENSITIES--RATIONAL METHOD (Inches Per Hour) | 385 |
| 130. | PEAK DISCHARGE WS-1 RATIONAL METHOD (Cubic Feet Per Second) | 387 |
| 131. | PEAK DISCHARGE WS-6 RATIONAL METHOD (Cubic Feet Per Second) | 387 |

## LIST OF TABLES (continued)

Table Page

132. PEAK DISCHARGE WS-7 RATIONAL METHOD (Cubic Feet Per Second) 388

133. PEAK DISCHARGE WS-8B RATIONAL METHOD (Cubic Feet Per Second) 388

134. PEAK DISCHARGE WS-8D RATIONAL METHOD (Cubic Feet Per Second) 389

135. PEAK DISCHARGE WS-10A6 RATIONAL METHOD (Cubic Feet Per Second) 389

136. PEAK DISCHARGE WS-BOWL RATIONAL METHOD (Cubic Feet Per Second) 390

137. 24-HOUR RAINFALL--CULBERSON COUNTY, TEXAS 386

138. RUNOFF CURVE NUMBERS FOR SELECTED LAND USES AND HYDROLOGIC SOIL GROUPS 391

139. COMPOSITE RUNOFF CURVE NUMBERS 393

140. SUMMARIZATION OF PRECIPITATION EVENTS WITH DURATIONS EQUAL OR GREATER THAN TIME OF CONCENTRATION 401

141. RAINFALL EVENTS EXCEEDING HISTORICAL ONE-YEAR STORM 402

142. UNIT PEAK DISCHARGES--SOIL CONSERVATION SERVICE METHOD 402

143. HYDROLOGIC CHARACTERISTICS OF SELECTED WATERSHEDS 404

144. EQUIVALENT TERMINOLOGY 421

145. LANDSCAPE UNIT 32 SITE DESCRIPTIONS 431

146. HYPOTHETICAL SIMILARITY LEVEL TEST FOR SLOPE FACTOR 433

147. HYPOTHETICAL SIMILARITY LEVEL TEST FOR ALL FACTORS 434

148. HYPOTHETICAL COMPARISON OF DOMINANT DISTINCT UNITS 436

149. PAIRWISE COMPARISON FOR SLOPE FACTOR (MINIMUM PERCENT AGREEMENT) 440

150. PAIRWISE COMPARISON FOR VEGETATION FACTOR (MINIMUM PERCENT AGREEMENT) 441

151. PAIRWISE COMPARISON FOR GEOLOGY FACTOR (MINIMUM PERCENT AGREEMENT) 442

152. COMPARISON OF DOMINANT DISTINCT UNITS 444

153. MOST SIMILAR WATERSHED PAIRS--LANDSCAPE UNITS 455

154. MOST SIMILAR WATERSHED PAIRS--HYDROLOGIC VARIABLES 457

# LIST OF FIGURES

| Figure | | Page |
|---|---|---|
| 1. | Vicinity Map. | 5 |
| 2. | Satellite photograph of the Guadalupe Mountains with Park boundaries superimposed. (Skylab Photo SL2-04-291). | 6 |
| 3. | El Capitan -- eastern escarpment. | 7 |
| 4. | Northcentral portion of the park in the Dog Canyon watershed area. | 7 |
| 5. | Remains of the Pinery Stage Station near the mouth of Pine Canyon. | 14 |
| 6. | Frijole Ranch Headquarters near Frijole Spring. Currently used as a Park Service residence. | 14 |
| 7. | Erosion damage to primitive road on westside of Park. | 17 |
| 8. | Arroyo head cutting in West Dog Canyon near northern Park boundary. | 17 |
| 9. | Total yearly visitation, Guadalupe Mountains National Park. | 21 |
| 10. | Watershed Delineations. | 34 |
| 11. | Watershed Clusters. | 42 |
| 12. | Profile through El Capitan showing inferred relations following deposition of Brushy Canyon formation (A) and following deposition of the Capitan reef (B). Vertical exaggeration, X 2. 1, Cutoff member, Bone Spring formation; 2, base of Cutoff member in Delaware Basin; 3, Waagenoceras shale (southern Cutoff of P. B. King, 1948), basal member, Brushy Canyon formation. (After P. B. King, U. S. Geol. Survey, Prof. Paper 215, 1948.), from Newell, et. al., 1953, p. 17. | 46 |
| 13. | Inferred hydrographic relations in Delaware Basin, (A) during Wolfcampian and Leonardian times, and (B) during late Guadalupian time. During early stages surface waters sank because of winter cooling, resulting in convective overturn and partial ventilation of deep waters. During late history (B) gradual concentration of hypersaline waters below the level of the threshold and deepening of the basin favored complete stagnation below the threshold level. Ventilation of the deeper part of the basin was incomplete throughout much of Permian time; hence, prevailing negative values of Eh and low pH. Conditions were favorable for accumulation of organic material and were unfavorable for precipitation of calcareous sediments (from Newell, et. al., 1953, p. 193.). | 48 |

## LIST OF FIGURES (continued)

| Figure | | Page |
|---|---|---|
| 14. | Diastrophic factor in reef growth. (Basin sediments represented by black; the sea, by white; top of each diagram represents sea level.) A, Diastrophic stability; reef is near sea level, the only possible growth is horizontal. B, Subsidence rapid relative to rate of growth, so that reef expansion is mainly upward. C, Subsidence slow relative to rate of growth, so that reef expansion is obliquely upward. The last example is the type to which the Capitan and Goat Seep reefs belong (from Newell, et. al., 1953, p. 106.). | 48 |
| 15. | Evolution of reef, shelf, and basin environments during Guadalupian time. A, Early Brushy Canyon time. B, Getaway time, growth of small patch reefs. C, Late Cherry Canyon time, Goat Seep barrier reef. C, Early Bell Canyon time, Capitan barrier reef (from Newell, et. al., 1953, p. 104.). | 50 |
| 16. | Surface Rock Material Watershed 1. | 55 |
| 17. | Surface Rock Material Watershed 10A6. | 56 |
| 18. | Surface Rock Material Watershed 8B-8D. | 57 |
| 19. | Surface Rock Material Watershed 7. | 58 |
| 20. | Surface Rock Material Watershed 6. | 59 |
| 21. | Weather Station Locations. | 62 |
| 22. | NOAA Precipitations and Temperature Recording Station Locations. | 64 |
| 23. | Precipitation gage and instrument enclosure. Location WS-6. | 65 |
| 24. | Propane heated snow gage with Alter windshield. Location WS-1. | 65 |
| 25. | Hygrothermograph instrument shelter. Location WS-6. | 66 |
| 26. | Precipitation gage and mechanical pyranograph. Location WS-6. | 66 |
| 27. | Precipitation -- Station WS-1. | 68 |
| 28. | Temperature -- Station WS-1. | 70 |
| 29. | Relative Humidity -- Station WS-1. | 71 |
| 30. | Precipitation -- Station 8B-8D. | 73 |
| 31. | Temperature -- Station 8B-8D. | 74 |

LIST OF FIGURES (continued)

| Figure | | Page |
|---|---|---|
| 32. | Relative Humidity -- Station 8B-8D. | 75 |
| 33. | Precipitation -- Station WS-6. | 76 |
| 34. | Temperature -- Station WS-6. | 78 |
| 35. | Relative Humidity -- Station WS-6. | 79 |
| 36. | Average Daily Maximum Solar Radiation -- Station WS-6. | 81 |
| 37. | Precipitation -- Station 10A6. | 82 |
| 38. | Precipitation -- Station Bowl. | 85 |
| 39. | Vegetation Types Watershed 1. | 97 |
| 40. | Dry, Very Stony Slope (50%) Site; typical expression of the smallseed sacahuista-blue threeawn-sideoats grama community. | 99 |
| 41. | Smallseed sacahuista-sideoats grama community (Dry, Very Stony Slope (50%) Site). (Background: Heavily Oaken Slope (49%) Site; wavyleaf oak-New Mexico muhly community.) | 99 |
| 42. | Heavily Oaken Slope (49%) Site; wavyleaf oak-New Mexico muhly community (middle of photograph).<br>Immediate foreground: Open Ridgetop Site; smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community. | 111 |
| 43. | Right side: Dry, Very Stony Slope (50%) Site; smallseed sacahuista-blue threeawn-sideoats grama community.<br>Left side: Heavily Oaken Slope (49%) Site; wavyleaf oak-New Mexico muhly community. | 111 |
| 44. | Dry, Stony Slope (58%) Site; mountain mahogany-wavyleaf oak-New Mexico muhly community (ridges in lower left, midground framed by two pinyon pine trees). | 119 |
| 45. | Open Ridgetop Site; smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community. | 119 |
| 46. | Pinyon pine-finestem needlegrass community. | 125 |
| 47. | Valley Floor Site; alligator juniper-gray oak-sideoats grama community. (Meadow in center is the Meadow Site; finestem needlegrass community.) | 125 |
| 48. | Escarpment Site. | 137 |

## LIST OF FIGURES (continued)

| Figure | | Page |
|---|---|---|
| 49. | Wavyleaf oak-pine muhly community (Escarpment Site) (Foreground: Valley Floor Site; alligator juniper-gray oak-sideoats grama community). | 137 |
| 50. | Background: wavyleaf oak-smallseed sacahuista-pine muhly-bull muhly community (Escarpment site). Foreground: Valley Floor Site; alligator juniper-gray oak-sideoats grama community. | 140 |
| 51. | Foreground: overview of Wooded Ridgetop Site, Lower Elevation.<br>Midground: Dry, Stony Slope (58%) Site.<br>Background: (Center and left) Wooded Ridgetop Site, Higher Elevations. Steeper areas at these higher elevations are in the Steep Wooded Slope (49%) site. | 140 |
| 52. | Ponderosa pine-alligator juniper-pine muhly-bull muhly community within the ponderosa pine-alligator juniper-pine muhly community complex (Wooded Ridgetop Site). | 144 |
| 53. | Ponderosa pine-alligator juniper-pine muhly community within the ponderosa pine-alligator juniper-pine muhly community complex (center and right) (Wooded Ridgetop Site). | 144 |
| 54. | Wavyleaf oak-mountain mahogany-plains lovegrass-pine muhly community (Wooded Ridgetop Site). | 148 |
| 55. | Pinyon pine-New Mexico muhly community (Wooded Ridgetop Site). | 148 |
| 56. | Steep Wooded Slope (49%) Site; Douglas fir- New Mexico muhly community. | 155 |
| 57. | Foreground: Ponderosa pine-wavyleaf oak-New Mexico muhly community (Steep Wooded Slope (49%) site). | 155 |
| 58. | Steep Intermediately Wooded Slope (50%) Site; alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community. | 159 |
| 59. | Steep Intermediately Wooded Slope (50%) Site; (Western Aspect); variation of alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community. | 159 |
| 60. | Steep Intermediately Wooded Slope (50%) Site; (Eastern Aspect); variation of alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community. | 161 |

## LIST OF FIGURES (continued)

| Figure | | Page |
|---|---|---|
| 61. | Foreground: PX Ridge Site (Western Aspect); javelina bush-curlyleaf muhly community.<br>Middleground: PX Flat Site; oneseeded juniper-blue grama community.<br>Background: PX Ridge Site (Eastern Aspect); smallseed sacahuista-curlyleaf muhly-New Mexico feathergrass community. | 161 |
| 62. | Vegetation Types Watershed 10A6. | 168 |
| 63. | Javelina bush-curlyleaf muhly community (PX Ridge Site). | 171 |
| 64. | Background: javelina bush-curlyleaf muhly community (PX Ridge Site). Note pinyon pine growing up the small channels traversing this aspect.<br>Midground: PX Flat Site; oneseeded juniper-blue grama community. | 171 |
| 65. | Background: smallseed sacahuista-curlyleaf muhly-New Mexico feathergrass community (PX Ridge Site).<br>Foreground: part of the mat muhly-blue grama community inclusion within the PX Flat Site.<br>Midground: PX Flat Site; oneseeded juniper-blue grama community. | 173 |
| 66. | Mountain mahogany-New Mexico muhly-New Mexico feathergrass community (PX Ridge Site). | 173 |
| 67. | Oneseeded juniper-blue grama community (PX Flat Site). | 179 |
| 68. | Oneseeded juniper-blue grama community (PX Flat Site). Background: PX Ridge Site; Western (left) and Northern (right) aspects. | 179 |
| 69. | Mat muhly-blue grama community (inclusion within PX Flat Site). | 181 |
| 70. | Creosote Site; creosotebush-Sporobolus-black grama community. | 181 |
| 71. | Range ratany-skeleton goldeneye-fluffgrass community (Creosote Site). | 187 |
| 72. | Background: Southern aspect of the Outcrop Site; skeleton goldeneye-gray coldenia-slim tridens community.<br>Foreground: Cresote Site; creosotebush-Sporobolus-black grama community. | 187 |

## LIST OF FIGURES (continued)

| Figure | | Page |
|---|---|---|
| 73. | Background: Northern aspect of the Outcrop Site; skeleton goldeneye-smooth sotol-Warnock grama-slim tridens community. | 192 |
| 74. | Background: creosotebush-pepperweed-Cryptantha community inclusion (dark patch of vegetation below saddle).<br>Foreground: range ratany-skeleton goldeneye-fluffgrass community of Creosote Site. | 192 |
| 75. | Gypsum Site; range ratany-creosotebush-Dyssodia-wooly Indian wheat community complex. Shrubs in background are mostly creosotebush. Understory vegetation is almost entirely Phacelia intermedia (foreground is a road). | 196 |
| 76. | Gypsum Site; range ratany-creosotebush-Dyssodia-wooly Indian wheat community complex. Compare vegetation and ground cover in this figure with Figure 75. | 196 |
| 77. | Gypsum Site; range ratany-creosotebush-Dyssodia-wooly Indian wheat community complex. Compare with Figures 75 and 76. | 197 |
| 78. | Channel Site; creosotebush-black grama community. | 197 |
| 79. | Vegetation Types Watershed 8B-8D | 201 |
| 80. | Shrub-Grassland Site; sandpaper oak-redberry juniper-curlyleaf muhly-Warnock grama community complex. | 203 |
| 81. | North Slope Shrubland Site; phase of the sandpaper oak-redberry juniper-curlyleaf muhly-Warnock grama community complex. | 203 |
| 82. | Grassland Ridge Site; blue grama-hairy tridens community. | 209 |
| 83. | Grassland Meadow Site; blue grama-black grama community. | 209 |
| 84. | Vegetation Types Watershed 7. | 214 |
| 85. | Background (center and right): Steep Open Slope; skeleton goldeneye-New Mexico muhly-sideoats grama community.<br>Foreground: Shrub Slope-Bench Site; Quercus-redberry juniper-plains lovegrass community. | 216 |
| 86. | Lowest Elevation Ridge (5270 ft.) Site; lecheguilla-skeleton goldeneye-curlyleaf muhly community. | 216 |

## LIST OF FIGURES (continued)

| Figures | | Page |
|---|---|---|
| 87. | Steep Southern Ridge Site; Quercus-smooth sotol-sideoats grama-littleawn needlegrass community. | 226 |
| 88. | Steep Northeastern Ridge Site; Quercus-smooth sotol-mountain mahogany-littleawn needlegrass community complex. | 226 |
| 89. | Shrub Slope Bench Site; gray oak-sideoats grama-plains lovegrass. | 232 |
| 90. | Shrub Slope Bench Site; catclaw mimosa-Engelmann pricklypear-blue grama. | 232 |
| 91. | Grassland Bench Site; redberry juniper-hairy grama-blue grama community. | 238 |
| 92. | Foreground: Dry, Stony Slope (58%) Site; mountain mahogany-wavyleaf oak-New Mexico muhly community | 238 |
| 93. | Vegetation Types Watershed 6. | 241 |
| 94. | Bowl Site; ponderosa pine-Arizona fescue-pringle needlegrass community. | 247 |
| 95. | Rocky, Lower Slope (5800 ft.) Site; wavyleaf oak-smooth sotol-bull muhly-pine muhly community. | 247 |
| 96. | Rocky, Lower-Slope (5800 ft.) Site; smooth sotol-wavyleaf oak-sideoats grama-bull muhly community. | 252 |
| 97. | Steep Open Site; wavyleaf oak-smooth sotol-sideoats grama community. | 252 |
| 98. | Creek Bottom Site; redberry juniper-smooth sotol-hairy grama community. | 258 |
| 99. | Creek Bottom Site; chinkapin oak-big-tooth maple-wavyleaf oak community. | 258 |
| 100. | Soil Types Watershed 1. | 262 |
| 101. | Soil Types Watershed 10A6. | 263 |
| 102. | Soil Types Watershed 8B-8D. | 265 |
| 103. | Soil Types Watershed 7. | 267 |
| 104. | Soil Types Watershed 6. | 269 |
| 105. | Site 1S. (Watershed 10A6). | 297 |
| 106. | Site 1N. (Watershed 10A6). | 297 |
| 107. | Site 2S. (Watershed 7). | 298 |
| 108. | Profile at Site 2S. (Watershed 7). | 298 |

## LIST OF FIGURES (continued)

| Figure | | Page |
|---|---|---|
| 109. | Site 2N. (Watershed 7). | 299 |
| 110. | Profile at Site 2N. (Watershed 7). | 299 |
| 111. | Site 3S. (Watershed 6). | 300 |
| 112. | Profile at Site 3S. (Watershed 6). | 300 |
| 113. | Site 3N. (Watershed 7). | 301 |
| 114. | Profile at Site 3N. (Watershed 6). | 301 |
| 115. | Monthly Soil Temperatures at Site 1 (Watershed 10A6). | 310 |
| 116. | Monthly Soil Temperatures at Site 2 (Watershed 7). | 311 |
| 117. | Monthly Soil Temperatures at Site 3 (Watershed 6). | 312 |
| 118. | North Aspect Soil Temperatures at the Three Study Sites. | 314 |
| 119. | South Aspect Soil Temperatures at the Three Study Sites. | 315 |
| 120. | Diffractograms of Selected Horizons on South and North Aspects Site 1. | 325 |
| 121. | Diffractograms of Selected Horizons on South and North Aspects Site 2. | 326 |
| 122. | Diffractograms of Selected Horizons on South and North Aspects Site 3. | 327 |
| 123. | Sampled Spring Locations. | 335 |
| 124. | Upper Pine Spring. | 345 |
| 125. | Bone Spring. | 345 |
| 126. | Smith Spring. | 346 |
| 127. | Guadalupe Spring. | 346 |
| 128. | Manzanita Spring. | 347 |
| 129. | Frijole Spring. | 347 |
| 130. | Choza Spring. | 348 |
| 131. | Upper Dog Canyon Spring. | 348 |
| 132. | McKittrick Stream location of sample sites. | 350 |
| 133. | McKittrick Stream Sample Site Elevations. | 351 |
| 134. | South McKittrick Stream--Sample Site #3. | 352 |
| 135. | South McKittrick Stream--Sample Site #1. | 352 |
| 136. | South McKittrick Stream--Sample Site #6. | 353 |

## LIST OF FIGURES (continued)

| Figure | | Page |
|---|---|---|
| 137. | South McKittrick Stream--Sample Site #2. | 353 |
| 138. | Pratt Lodge Well. | 354 |
| 139. | South McKittrick Stream--Sample Site #4. | 354 |
| 140. | Main McKittrick Stream--Sample Site #7. | 355 |
| 141. | South McKittrick Stream--Sample Site #5. | 355 |
| 142. | Main McKittrick Stream--Sample Site #8. | 356 |
| 143. | Main McKittrick Stream--Sample Site #9. | 356 |
| 144. | Topographic Map of the Pratt Lodge Area. | 358 |
| 145. | Specific conductance levels for the springs. | 364 |
| 146. | Transect and cross-section locations--Watershed 1. | 370 |
| 147. | Transect and cross-section locations--Watershed 10A6. | 371 |
| 148. | Transect and cross-section locations--Watershed 8B-8D. | 372 |
| 149. | Transect and cross-section locations--Watershed 7. | 373 |
| 150. | Transect and cross-section locations--Watershed 6. | 374 |
| 151. | Rock cairn around survey monument, Watershed 1, Location 2. | 375 |
| 152. | Survey monument (steel stake), Watershed 8B, Location 2. | 375 |
| 153. | Survey monument (at level rod), Watershed 8B, Location 2. | 376 |
| 154. | Flood debris in McKittrick Canyon. Debris at right is from 1978 Storm. Debris in tree at center is from a previous storm. | 376 |
| 155. | Erosion on trail in McKittrick Canyon. | 379 |
| 156. | Flood debris in McKittrick Canyon from a storm prior to September, 1978. | 379 |
| 157. | Rainfall intensity curves (Texas Highway Department, 1970.). | 383 |
| 158. | Unit hydrograph--Watershed 1. | 395 |
| 159. | Unit hydrograph--Watershed 6. | 396 |
| 160. | Unit hydrograph--Watershed 7. | 397 |
| 161. | Unit hydrograph--Watershed 8B. | 398 |
| 162. | Unit hydrograph--Watershed 8D. | 399 |

## LIST OF FIGURES (continued)

| Figure | | Page |
|---|---|---|
| 163. | Unit hydrograph--Watershed 10A6. | 400 |
| 164. | Rock cairns around erosion transect monument. Watershed 7, location 4. | 406 |
| 165. | Erosion transect at location 5 in the Bowl across Bush Mountain trail. | 407 |
| 166. | Cable stretched for making erosion transect at location 2 of Watershed 10A6. | 407 |
| 167. | Landscape Units in Guadalupe Mountains National Park. | 428 |
| 168. | Landscape Unit 32. | 430 |
| 169. | Watershed Clusters -- Landscape Unit Approach. | 456 |
| 170. | Watershed Clusters -- Hydrologic Variable Approach. | 458 |

# CHAPTER I INTRODUCTION

## RELEVANCE OF RESEARCH

In the Southwest, as in most other parts of the United States, there is widespread concern about the hydrologic effects of a rapidly increasing population and the consequent drastic changes in the types and intensity of land use. The concern is particularly justified in the Southwest for three reasons: (1) its rate of population increase is one of the highest in the country; (2) even the fairly low levels of population and land use of the past, have apparently caused some significant hydrologic disturbances; and (3) the damage caused by high populations, intensive land use, and lack of ecologic consideration in the fragile arid and semiarid environments of the Old World are well known.

Predictions vary widely as to the possible consequences of recreational development and intensified land use-- which is not surprising considering that even today there is controversy on the nature and causes of the ecological changes observed in the past 50 to 100 years. The widespread valley trenching (or arroyo cutting) since about 1880 is a good example. Conservationists have generally blamed overgrazing for this phenomenon. Many geologists, however, have attributed it to climatic changes, pointing out that such periods of downcutting have occurred several times in the past few thousands years. The extent and causes of brush invasion during the same period constitute another area in which there is little agreement among scientists. These controversies exist because there is little reliable quantitative evidence available and because, until recently, there has been little attempt at interdisciplinary study of such problems.

Presently, a situation exists which has provided an opportunity to begin just such an interdisciplinary study of the effects of recreational development in a portion of the Southwest. The National Park Service has established and begun to manage a 31,376 hectare (77,500 acre) area in the Guadalupe Mountains of Texas. Several development proposals have been suggested and base line environmental studies are being conducted. It currently appears that there will be a general rapid expansion of wilderness type recreational activities in all areas of the park over the next several years and development of higher intensity uses at selected sites within the park. We feel that this situation offered an excellent and unusual opportunity to begin monitoring the responses of hydrologic systems to a drastic alteration in land use.

To our knowledge no study of the same design as the one we have conducted has been attempted in the past. Numerous experimental watersheds have been established to study the effects of grazing, logging, and vegetation conversion on runoff, water yield, and erosion, but these have not generally, if ever, included study of recreational development as a land use. In those few studies that have attempted to appraise the effects of recreation, the studies have generally been initiated after development has taken place, and consequently the pre-recreation conditions could not be adequately assessed. Thus, documentation of watershed characteristics before extensive recreational development and the monitoring of the changes that occur during the course of development is, we believe a unique approach.

Final evaluation of the effects of recreational land use obviously cannot be achieved in the time span of the present study, but the initial state of the area can be documented and preliminary changes observed. Likewise, erosion rates cannot be completely characterized in such a short period of time, but valuable benchmarks can be established for further observation in the future. Dr. Luna Leopold expressed the importance of such information in the discussion following his paper at an international symposium when he said, "The measurement methods described here have their value in time effects, and it is our duty to scientists of the future to provide data that can be compared with conditions found by them at their time. The long-range importance of documentation has been realized by many, but few are willing to invest time and work now for the use of future scientists." (Miller and Leopold, 1963).

## OBJECTIVES

The main objectives of this investigation were as follows:

To study the relationships among soils, vegetation, parent materials, climate, geomorphic surfaces, topography, and current land use in the Guadalupe Mountains National Park of southwest Texas, and to relate these factors to the surface and ground water hydrology, erosion, sedimentation, and chemical water quality.

To establish, as closely as possible, the changes that have occurred in the past in regard to climate, vegetation, erosion, and surface and ground water hydrology, and to relate these to the land use history including grazing, road construction, fire, and human culture.

To study the changes in vegetation, sedimentation, erosion, and surface and ground water quality and yield that are occurring as this area becomes increasingly developed for recreational land use.

From the results of this study we can accomplish the following:

Extend our understanding of changes in vegetation and soil erosion that have occurred in the recent past.

Provide an explanation of the basic relationships between soil and vegetation characteristics and the formative climatic, topographic, geologic, biotic, and time factors that will aid in classifying the land according to its use capabilities and restrictions, particularly with respect to recreational development.

Quantify the observed relationships in such a way that they may be used as a basis (model) for predicting the effects of modification in land use or drainage characteristics on erosion, sedimentation, water yield and quality, flood problems, and ground water supplies.

Suggest ways of minimizing hydrologic disturbance in future recreational land development projects.

Provide a pool of hydrologic information to which other more specific studies may be tied, and their results extended, especially those studies planned for the Guadalupe Mountains National Park development program.

The rapid increase in the Southwest's population is brought about by people's desire to work and retire in the healthy and pleasant environment of the Southwest. We believe that the type of information obtained from this study is essential for the diligent management of our nation's finite natural resources to assure that this quality of living and environment can be maintained.

## STUDY LOCATION

Guadalupe Mountains National Park was authorized by Public Law 89-667, October 15, 1966, "To preserve in public ownership an area in the State of Texas possessing outstanding geologic values of great significance" (National Park Service, 1973). Formal dedication and establishment of the park occurred on September 30, 1972 following the acquisition of all properties within the present boundaries.

Located on the southern end of the Guadalupe Mountains in southwest Texas the park is approximately mid-way between El Paso, Texas and Carlsbad, New Mexico. (Figure 1). The nearest settlement is Dell City, Texas, population 600, located in the Salt Basin west of the park. Primary access to the region is via U.S. 62-180 between El Paso and Carlsbad. The park is bounded by the Lincoln National Forest on the north in New Mexico. Elsewhere the lands surrounding the park are in private ownership and used primarily for grazing.

The Guadalupe Mountains themselves are composed largely of limestone, a remnant of a huge reef called the Capitan Barrier Reef. But for the slow, inexorable tectonic movements in the area, the reef would have remained buried. Now a part of that reef rises precipitously to an elevation of 2,667 meters (8,749 feet) above mean sea level. The mountains form a 'V' shape, the apex of which points south and culminates abruptly in El Capitan, a prominent scarp face (Figures 2-3-4). The park has the distinction of containing within its boundaries the entire gamut from xeric desert shrub to mesic coniferous forest and including animals as diverse as cottontails and mountain lions, porcupines and elk (National Park Service, 1973). Austin (1965) has classified the

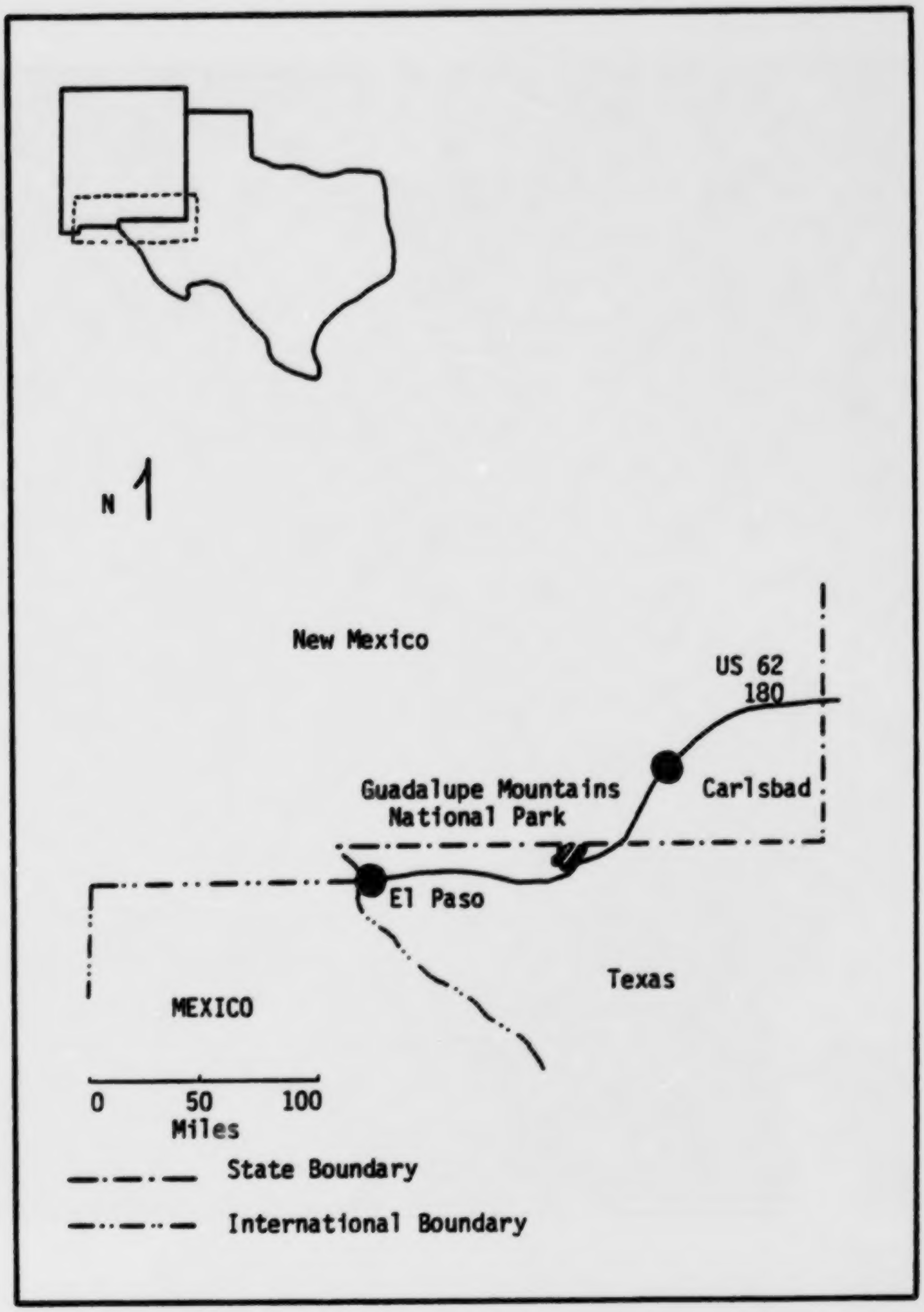

Figure 1. Vicinity Map.

Figure 2. Satellite photograph of the Guadalupe Mountains with Park boundaries superimposed. (Skylab Photo SL2-04-291).

Figure 3. El Capitan -- eastern escarpment.

Figure 4. Northcentral portion of the park in the Dog Canyon watershed area.

area as lying with two Land Resource Regions: (1) the southern desertic basins, plains, and mountains segment of the Western Range; and (2) the Irrigation Region of the Pecos-Canadian plains and valley segment of the Western Great Plains Range and Irrigated Region.

## REPORT FORMAT

The remainder of this report will deal with specific segments of the project on a chapter by chapter basis. The chapters have been established on a topic foundation which hopefully will assist both the general reader and the reader in search of a particular aspect of the project.

Chapter III -- Watershed Inventory Studies discusses the initial investigations which were broadly based and included the entire park. From these initial studies specific watersheds were selected for more intensive investigations which are then discussed in subsequent chapters.

Chapter X presents a non-traditional approach to the analysis of watershed similarities based on a holistic technique involving the recognition and delineation of landscape units.

# CHAPTER II HISTORY OF MAN'S IMPACT ON GUADALUPE MOUNTAINS NATIONAL PARK

The impact of man in the Guadalupe Mountains appears limited when compared to other intensively utilized regions in the Southwest. The initial impression is that of a wilderness setting with varying natural vegetation which dominates this diverse area. Various studies have documented the existence of unique, rare, and in some cases fragile communities within the park (Northington, 1975; National Park Service, 1975; Gehlbach, 1967, 1969). According to some ecologists this in itself would indicate environmental impacts or alterations by man have been limited. Greater diversity within a community is generally indicative of fewer negative impacts on that community (Odum, 1971; Ehrlich and Ehrlich, 1970). However, studies have shown that while man's impacts have been limited, in an arid environment even minimal impacts can be significant (Kitchen and Griggs, 1973; Kurtz and Goran, 1978). Beginning with prehistoric inhabitants of natural shelters within the area, until establishment of the national park, men occupying this region have left their mark as monuments of their efforts to conquer an unforgiving environment.

## PREHISTORIC AND HISTORIC ACTIVITIES

The Guadalupe Mountains as a remnant of a massive limestone barrier reef which was uplifted, exposing it to weathering and erosive forces, contain numerous shelter caves and caverns, which became the first dwellings in this region. Archeological investigations have substantiated man's occupation of caves in the Southwest region for at least 12,000 years (Spangle, 1960). During this early occupation, nomadic groups concentrated their efforts toward collection of an adequate food supply. Basic characteristics of this economy, and harshness of the region limited populations of the prehistoric inhabitants. These limiting factors also restricted the inhabitants' impact on their environment.

By studying the few remnants of man's early existence in the Southwest his basic lifestyle has been pieced together and it is primarily a study in survival. Food, fibers, tools, and shelter were procured or produced from natural materials, resulting in some minor impacts on the environment. Time has erased most of these impacts; however a few, such as fire rings of ancient camps; hieroglyphs depicting forgotten cultures; weapons and tools; and shattered pottery, remain to testify that this region's first inhabitants had an influence on the landscape. Interestingly, these impacts have enhanced the present recreation-scientific use of this area, providing a significant resource for studying ancient cultures.

Modern Indians, which followed, were much like their predecessors, existing with an economy based on what was available from their natural surroundings. Tribes of the Trans-Pecos region were also fierce marauders, raiding settlements along the Rio Grande and deep into Mexico. The rugged terrain of the Guadalupe Mountains afforded an isolated sanctuary for these tribes, and many military pursuits ended at the base of the mountains (Raht, 1919).

Again time has taken its toll and the impacts from semi-permanent camps established in the park have become faint and very rare, yet still remain significant as a cultural resource. Impacts on vegetation and soils at many of these sites have since recovered or been obliterated by a more recent impact. Site occupation in the park was and continues to be rather restrictive, in that water availability is a limiting factor. Therefore, an area adjacent to a water supply, which offers adequate shelter and could be protected, has more than once been occupied over the years (National Park Service, 1975).

During the latest era of aborigine occupation of Guadalupe Mountains, a new way of life was being established which was to have a lasting effect on the region as a whole. Most of the Southwest had been wandered by Spanish explorers by the early 1580's, leading to development of two Spanish trade territories. These trade centers and missionary settlements were centered around San Antonio, Texas and the rich mines and fertile fields surrounding Santa Fe, New Mexico. To provide protection and link these two areas, a line of presidios was established along major drainages in the Southwest. The garrisons stationed at these fortifications provided protection to settlements and travelers in the region for nearly a century. However, by 1810 the presidio system had faded and most fortifications were abandoned (Raht, 1919).

The Spanish lifestyle established during this era had only an indirect impact on the Guadalupes. There is scattered evidence of Spanish presence in the park, attributed mainly to military maneuvers or occasional travelers. There are also some legends of lost Spanish gold mines in the Guadalupes; which claim mines existed that were some of the richest in the new world (Kurtz and Goran, 1978). Yet these impacts were slight in comparison to the impact of Spanish settlement on the Southwest as a whole.

Many of the tasks associated with settlement of a new territory such as exploration, protection of settlements, and development of product markets were accomplished during Spanish domination. Three centuries of Spanish and Mexican sovereignty had primed the Southwest for Anglo westward expansion.

Two events occurring in the late 1840's provided the impetus for a vast westward expansion in the United States. Gold was discovered in California, and a treaty, ending the Mexican War, was signed (Gosdin, 1969). The terms of the Treaty of Guadalupe Hidalgo ending the Mexican War provided the United States with additional territories. These territories set the present Mexico-United States border and included the Guadalupe Mountains. This treaty legalized American settlement in large portions of the Southwest.

The discovery of gold in the west did more to speed westward expansion than any other single event. Fortune seekers began their rush west, traveling through intervening areas such as the Guadalupes.

Overland routes west had been explored and surveyed and the Southern all-weather routes were of particular interest. Two of these Southern trails passed through the Trans-Pecos region leading through Limpia Canyon and the Davis Mountains, and one further north over Guadalupe Pass. The route over Guadalupe Pass proved to be shortest and presented "no obstructions to the easy passage of wagons." (U.S. Congress, Senate, 1849).

The trail west was far from ideal. The presence of Mescalero Apaches, and Comanches was a major deterrent during the 1800's. Water along the route was scarce to nonexistent for long distances. However, many of the 49'ers traveled this route, camping near springs at the base of the east escarpment and then traveling on through the Salt Flats to El Paso. It proved to be a dry, dangerous journey, which many did not complete; but, the lure of the gold fields in California persuaded thousands to attempt the arduous ordeal. Thus, a route west was established and remains a permanent impact on the park. Today, highway 62-180 passes through the east portion of the park, approximately following the same route established in the 1840's.

Westward expansion motivated Congress to authorize the U.S. Army Topography Corps to conduct surveys of the most practical route for a transcontinental railroad. Captain John Brevent Pope surveyed much of the "32nd parallel route" between the Red River and the Rio Grande. In his diary, Pope (1854), wrote of the Guadalupes, that the west face had no water or firewood; however, there was fine grama-grass and some sand. The east slope at the Pinery had an abundance of water, wood, grass, and a fine pine forest on the mountain slopes. Pope was very enthusiastic about the route; however, lack of sufficient water prohibited establishment of a railroad along this corridor.

This route was, however, established as a transcontinental mail route in 1858. The Overland Mail Company constructed the highest staging station along the Butterfield trail near Pine Spring. At the Pinery Station, as it was called, water, shelter and adequate forage was available. Although the stagecoaches rattled through Guadalupe Pass for only eleven short months, before the route was shifted south, they added much to the colorful history of the park. The Pinery Station lies in ruin today, with a few timbers and rock walls to mark its passing; yet, it represents another limited, but significant impact which enhances the cultural and recreational resources of the Park Service (Figure 5).

Having begun on September 16, 1858 the mail stages operated with astonishing regularity between St. Louis and San Francisco for two and one-half years. During this short period tremendous changes occurred in West Texas. By 1860, Fort Davis and Fort Stockton had been established, and communities were springing to life around the Trans-Pecos region. Presidio and El Paso were both thriving (Raht, 1919). The vastness of the country was still present and the Indian threat continued; however, civilization had gained a foothold.

Development of the Southwest received a setback during the Civil War due to the removal of federal troops from the region. Most settlers had left the area to join their favorite army; or, to avoid the conflict, had gone to Mexico. During this period the Apache regained much of his previous dominion.

Following the Civil War federal troops regained a stronghold in the Trans-Pecos and resumed their offensive harassment of the Apaches. Within thirteen years the final Indian battle had been fought in Texas. A small band was chased by a company of Texas Rangers into the Diablo Mountains where they were surprised and slaughtered on a plateau within sight of El Capitan (Kurtz and Goran, 1978). Thus, the Guadalupes were free from Indians and safe for settlement.

The Civil War had sharply increased the demand for cattle in the east. Men returning from the war found an abundance of derelict herds roaming the open ranges of Texas. Years prior, Pope had made a far-sighted observation as he noted the economic potential of West Texas. He wrote in his report to Congress:

> The grama-grass, which exists in the most profuse abundance over the entire surface of these table-lands, is nutritious during the whole year, and the Pecos seem intended by nature for the maintenance of countless herds of cattle. (Pope, 1854)

Demands for the cattle and rangeland were primary factors which now brought people to the Guadalupes.

Ranching in the area got its start in 1869 when Captain Felix McKittrick moved to the mouth of the Canyon, which now bears his name,

Figure 5. Remains of the Pinery Stage Station near the mouth of Pine Canyon.

Figure 6. Frijole Ranch Headquarters near Frijole Spring. Currently used as a Park Service residence.

and began running cattle on the open ranges to the east. The first permanent ranch house was not built until 1876. The Rader brothers constructed this dwelling near Frijole Spring, where it is still standing and in use today (Figure 6). By the turn of the century the single ranch house and a few dugouts were the extent of the dwellings making up the cattle industry within the park area (Kitchen and Griggs, 1973).

Ranching began to flourish in the Guadalupes following homesteading legislation of the early 1900's which made it feasible for a family to acquire a small ranch. In its prime the ranching era consisted of numerous houses, pens, and other structures throughout the park. Ranching, within the park, was responsible for some of the greatest and most significant impacts on the land.

To analyze these impacts, a review of early travelers' accounts provide descriptions of the land prior to settlement. From these accounts an image of vast grasslands dotted with an occasional shrub can be drawn for the lower lands surrounding the Guadalupe Range. The salt flats and sand dunes were also present; which reflect the aridity that existed (Bartlett, 1965). To the east of the mountains several springs flowed, providing an abundant but isolated supply of water. There are several references to the heavy pine timber down the canyons and at the base of the mountains. Marcy (1859) suggested the likely future of this timber when he wrote:

> The mountains are covered on the eastern side with groves of large pine trees; and as this is the only kind of timber fit for building in this country, it may some day be useful.

Therefore, prior to settlement by cattlemen the Guadalupes were prime rangeland with an adequate supply of timber for construction, but a rather restrictive and seasonable supply of water (Marcy, 1859; Bartlett, 1965; Pope, 1854; Ormsby, 1954).

In contrast, at the height of ranching in this area water was piped and pumped to all sections of the range, supplying an abundance of water. Inasmuch as there was an adequate water supply, there became a shortage of grasses. The palatable forage deteriorated and shrubs and other noxious plants invaded the range. Some settlers who arrived in the lowlands at the turn of the century tell of lush grasslands which were being rapidly decimated. Watering holes in the Salt Flat Valley were surrounded by a thousand head of livestock. Today, range adjacent to a tank can hardly support fifteen head (Levy, 1971).

Drought and depression during the 1930's spelled defeat for many small ranches and farms adjacent to the Guadalupes. Larger operations acquired these, as they came available, and grew ever larger. Two men were the primary landholders in the next phase of the ranching era; J.C. Hunter, owner of most of the high country and the west side; and Wallace Pratt, owning McKittrick Canyon and much of the eastern escarpment. These two men had a respect for, and a desire to preserve and maintain the Guadalupe Mountains. When one realizes the attitude of exploitation which generally prevailed, these men seemed pure environmentalists of their time. However, their activities and those of the ranching era in general have had a significant impact on the landscape.

Water, as has been discussed, was a limiting factor initially to grazing livestock in this dry region. By 1940, Hunter and previous landowners had constructed an elaborate watering system supplying most of the range. The most notable and amazing being from Pine Spring up Bear Canyon to the Bowl. This system pumped water 2,500 vertical feet to a large storage tank at the head of Bear Canyon. Water was piped from there through gravity flow lines to other tanks throughout the high country. This was a prime example of the extent to which ranchers went to provide water for stock (Kitchen and Griggs, 1973).

As the range was utilized, other improvements were essential for efficient operation. Line camps, roads and trails were constructed to facilitate ranching operations. Several cabins or lodges were built during the 1930's and 1940's utilizing natural materials which were readily available. Hunter had a log cabin built in the Bowl, and both Hunter and Pratt built stone lodges in McKittrick Canyon. In addition to these structures, roads and trails were also built in these fragile areas. Roads constructed in the lowlands to the west of the mountains have caused severe erosion problems (Figure 7).

In addition to grazing stock throughout most of the park, the area was also used for hunting and other recreational activities. Elk, turkey, trout and bass were introduced to the area for sport. Pratt visited McKittrick Canyon during vacations to enjoy its unparalleled beauty. He felt it was the "most beautiful spot in Texas" (Griggs,

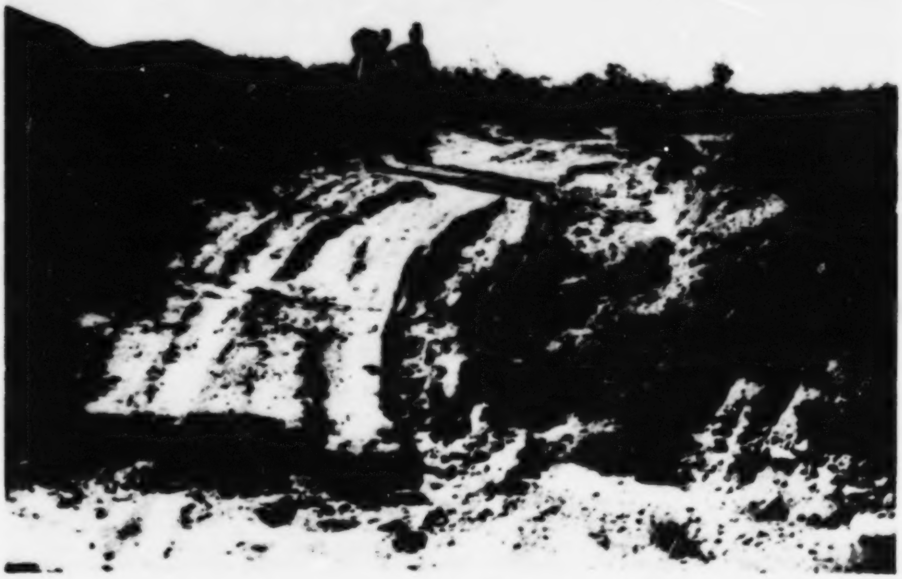

Figure 7. Erosion damage to primitive road on westside of Park.

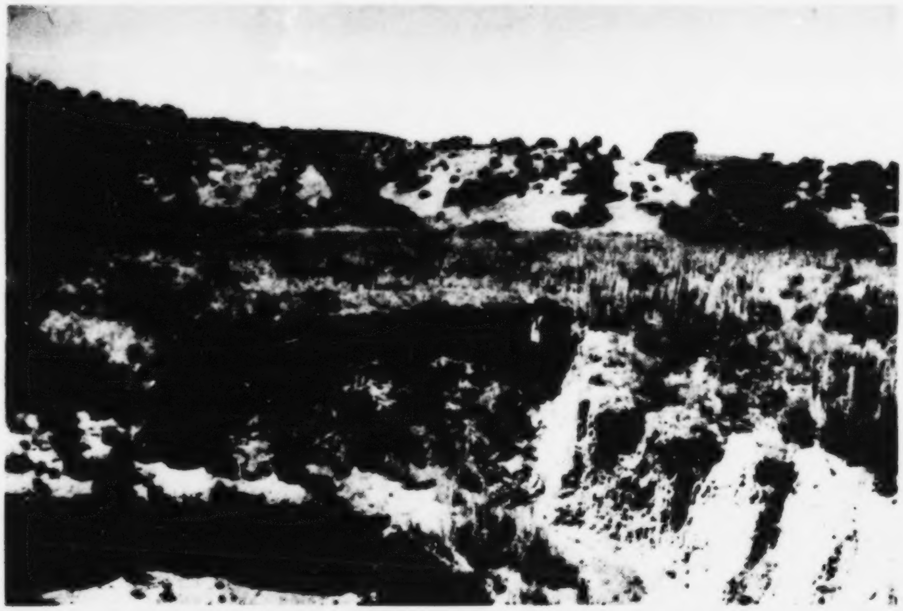

Figure 8. Arroyo head cutting in West Dog Canyon near northern Park Boundary.

1973). He retired in 1945 to a home built just southeast of the canyon, below the eastern escarpment. Pratt and Hunter both felt McKittrick Canyon should be preserved, therefore, grazing was restricted from the lower canyons.

Changes in vegetation and cultural improvements to the park, have resulted in accelerated erosion in many areas. As mentioned previously, roads on the west side and in other areas which disturbed ground cover have caused a noticeable removal of topsoil. In some cases ruts have become so deep, the original road is beyond repair and has been shifted to one side; more than once in some instances. Arroyo cutting along stream channels is also evident throughout the park (Figure 8). Pratt, reminiscing of his first view of McKittrick Canyon, tells of a stream running the full length of the canyon on a bed of hard travertine. This "bed," which must have taken thousands of years to create, was demolished during abnormally severe floods of 1943; leaving a barren jumble of naked limestone boulders and coarse gravel as a channel. The destruction of this stream and subsequent downcutting of the channel was a great loss to the scenic beauty of the area (Griggs, 1973).

Most of the changes which have occurred in the Guadalupe Mountains during the past century have a direct cause; that being the presence of man utilizing and in some cases exploiting, the natural resources which were available. However, many studies throughout the southwest address some of the changes which have occurred such as arroyo cutting and brush invasion, and cite natural phenomena as causes (Hastings and Turner, 1965; Bryan, 1925; Thornthwaite, et al., 1942; Bailey, 1935; Antevs, 1952). It is very likely that some of these changes are natural in origin, for we live in a dynamic ecosystem. However, there have been severe impacts resulting from man's activities within the park. Exactly to what degree grazing of the high country shares in the effect of flooding and downcutting in McKittrick Canyon, one can only guess. This question and others warrant further investigation, and may well never be resolved. Wallace Pratt put it aptly when he stated:

> We have learned a great deal about our Mother Earth, particularly in the last 200 years, but the most significant two things we have learned are: (1) how much we have learned is false - not true - and (2) how much there is that we still have to learn. (Griggs, 1973)

## RECENT ACTIVITIES

The Guadalupe Mountains have long provided a livelihood to those who sought it, but they have also, for many years, been a subject of interest for their scientific and recreational significance. Over the years numerous reports to both state and federal agencies have testified to their outstanding park potential (Gosdin, 1969). As early as 1924 suggestions had been made to establish a Texas State Park in the Guadalupe Peak-McKittrick Canyon area (Lee, 1925). However, due to remoteness and lack of political interest in the area no action was taken for many years. If not for the conservation practices of Mr. Wallace Pratt and Mr. J.L. Hunter, two principle owners for over forty years, this unique and fragile environment may have been lost.

The impetus for creation of the national park came when Mr. Pratt offered his 5,623 acre ranch as a donation to the National Park Service in 1959. This milestone began the long road to park designation and development. With the passing of Public Law 89-667, on October 15, 1966, Guadalupe Mountains National Park was authorized. The National Park Service has stressed the area's wilderness and unique scientific values in the development of the Park Master Plan, referring to the area as an "island in the desert."

Following enabling legislation various studies have been conducted, or are in progress, to develop a broad based data information system from which to plan and manage the park. Development of visitor access, circulation, and facilities is to be based on land capabilities derived from these baseline studies, in order to minimize visitor impact.

Prior to completion of these bio-physical inventories, and the finalization of a development plan, public access has been on somewhat of a limited basis, to reduce impacts on fragile areas. Unfortunately, those areas most fragile and least able to withstand visitor impacts, are of greatest interest to most park users. Control of utilization has been attempted in these areas by providing only primitive trails or roads for access, limited visitor facilities, and in some areas only allowing day use. These controls have reduced the total number of visitors who might enjoy experiences afforded by this unique environment to those willing and able to hike the park's interior trails.

However limiting these restrictions might seem, they are primarily controlling the type of use rather than the total intensity of use. The end result is an arbitrary and artificial "carrying capacity" which fluctuates with user demands for particular types of recreational experiences. As user demands for all types of activities have escalated since the park was established, so have the opportunities for intensified impacts on the park.

Visitation records, initiated in 1972, reflect a 157 percent projected increase in visits over an eight year period. It has been estimated that over 100,000 visitors will use the park during 1979 (Figure 9). Marlett and Mertes (1978) showed in a survey of visitor use that camping and hiking are activities most often sought in the park. Of those interviewed, 76 percent participated in camping and 63 percent backpacked or hiked in the park. The overall upward trend in use is again shown from the available visitation records (Table 1). A vast majority of those interviewed during the summers of 1976 and 1977 indicated they enjoyed the park, and 56 percent liked the primitive aspects of the park and wanted the park to remain "undeveloped" (Marlett and Mertes, 1978). These findings may suggest that the current "restrictive" management of the park is rather "selective" management and has a tendency to cater to a rapidly growing clientele of campers, hikers, and backpackers.

The ability to manage natural resources for long-term benefits with minimal adverse impacts on the resource implies a concept of carrying capacity. Central to this concept is the notion of a quantifiable definition of the level and type of usage which can be sustained over long periods of time under a given set of developmental and environmental circumstances. An example of a carrying capacity statement in the context of range management is contained in Range Management by Stoddart and Smith (1955) where they define grazing capacity as:

> . . . the maximum animal numbers which can graze each year on a given area of range, for a specific number of days, without inducing a downward trend in forage production, forage quality, or soil.

The parallel factors in a recreational carrying capacity statement could be numbers and types of users, duration of use, site disturbance indicators, and quality of the recreational experience.

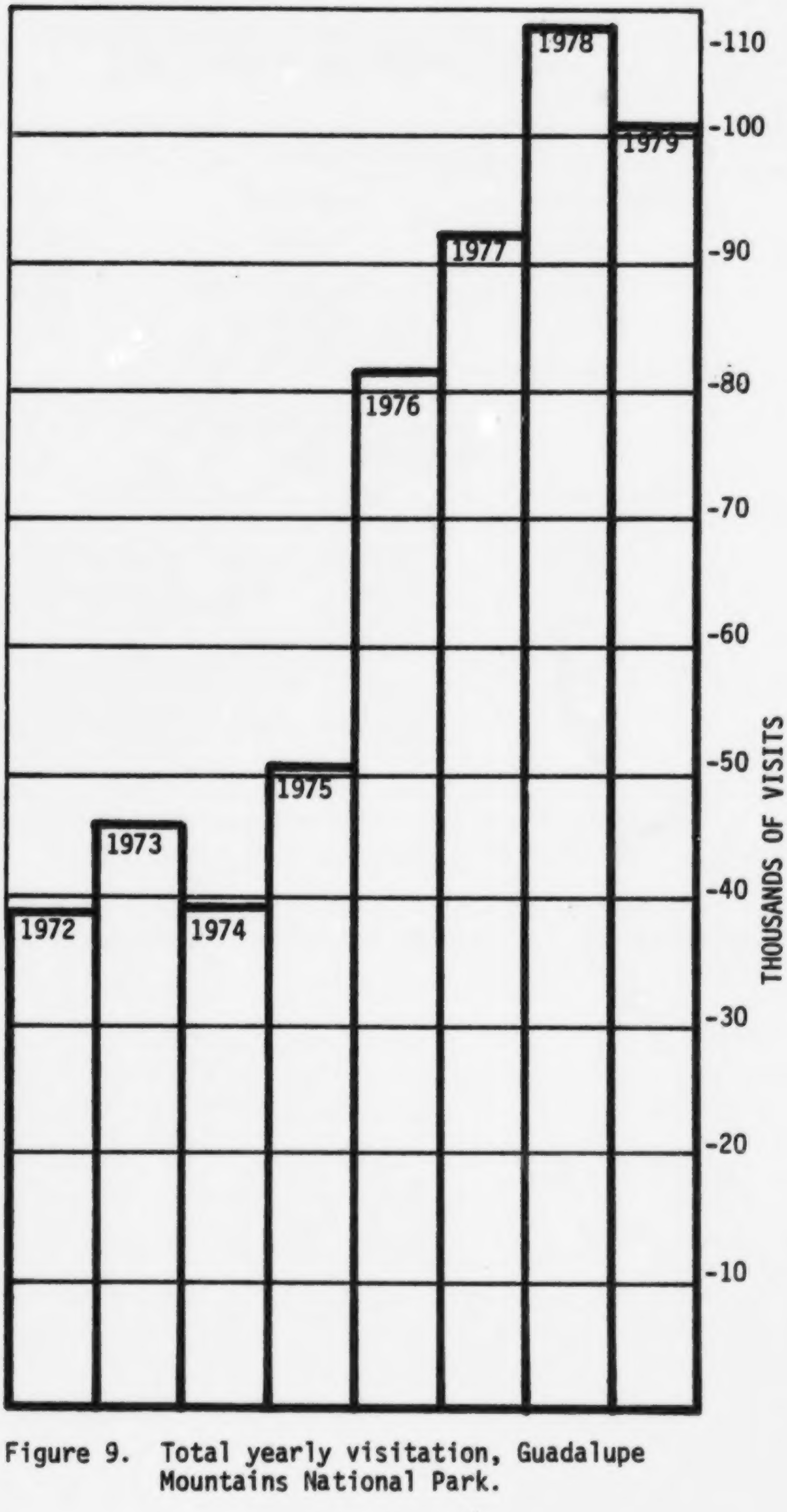

Figure 9. Total yearly visitation, Guadalupe Mountains National Park.

## TABLE 1. TRAIL USER DAYS AND OVERNIGHT STAYS FOR GUADALUPE MOUNTAINS NATIONAL PARK

Trail User Days

| | Backpacking | Dayhikers | Total |
|---|---|---|---|
| 1976 | 4,826 | 11,160 | 15,986 |
| 1977 | 4,266 | 17,814 | 22,080 |
| 1978 | 5,871 | 21,061 | 26,918 |
| 1979* | 5,007 | 24,126 | 29,133 |

NOTE: Trail use records were initiated in 1976.

Overnight Stays

| | Backcountry | Tent | R.V. | Total |
|---|---|---|---|---|
| 1972 | 884 | -- | -- | 4,506 |
| 1973 | 1,880 | 3,240 | 2,829 | 7,949 |
| 1974 | 1,774 | 3,841 | 2,549 | 8,164 |
| 1975 | 2,166 | 4,868 | 4,215 | 11,249 |
| 1976 | 2,791 | 5,478 | 4,894 | 13,163 |
| 1977 | 3,015 | 6,361 | 5,940 | 15,316 |
| 1978 | 3,575 | 7,699 | 6,460 | 17,734 |
| 1979* | 2,941 | 7,713 | 9,271 | 19,925 |

* Figures are projected from data available for 1979 visitation. See Appendix A for visitation data for specific areas.

National Park Service, Monthly Use Reports; submitted to Park Superintendent, from Park Ranger Supervisor, Guadalupe Mountains National Park. 1972-1979.

In determining carrying capacities for recreation management, at least three elements need to be considered. First, the recreation site will have a certain ecological carrying capacity that is a particular upper limit for a type or types of use up to which long-term sustained yield from the resource is obtained without deterioration of the ecosystem. A second element involves a limitation on facility use. Carrying capacity in this context is that upper limit of use at which routine maintenance can sufficiently keep the facility operable without deterioration. The third element involves the quality of the intended recreational experience. This limit will vary depending upon the type of activity and in particular with the user's expectation. For example, if a user expects and desires a wilderness type activity to "get away from people" then the acceptable carrying capacity of a given area will be much lower than if the user expected or anticipated frequent contact with other users as might happen along a nature trail.

Establishing carrying capacities is not a simple task and more often than not several iterations are required over a period of years before a reasonably sound value can be fixed for a particular situation. One of many difficulties encountered may well be an acceptable definition of what constitutes deterioration of a particular ecosystem. This is further complicated depending on the selection of baseline data to which current conditions will be compared.

Within the park many areas are being utilized, to various degrees, for a range of recreational purposes. As mentioned before, those environments which can least cope with heavy use are those most interesting and attractive areas, and subsequently receive the greatest use and impact. Sustained use carrying capacities for these areas are currently unknown, however, estimates have been extremely low (Gehlbach, 1967, 1969; Nat. Park Service, 1971). It is certain that without management policies to limit numbers of visitors rather than just types of visitors, these areas may be in jeopardy.

Through proper design and construction of improvements an area's carrying capacity for a particular type of use may be increased. Such improvements are designed to reduce the adverse impact on the resource by each individual user. For example if trails are designed and constructed with adequate tread widths and drainage a greater number of hikers can use the trail without causing an unacceptable level of accelerated erosion. Many of the trails presently in use for circulation throughout the park were constructed to minimal standards and do not fulfill current recreational trail design criteria. There are also numerous trails and roads throughout the park which have been officially closed, yet are unsigned or have not been revegetated. These "unofficial" trails encourage hikers into areas presumably protected from recreational impacts.

There are presently eight designated points of entry to the park. These range from high use areas, such as Pine Canyon Campground, to very isolated areas, such as the North McKittrick trail from Lincoln National Forest. The number of visitors using a particular point of access is dependent on the type of facilities provided and the publicity an area receives.

Pine Canyon Campground, the area receiving the greatest use, is located approximately one mile off highway 62-180 on a well-graded road. This area provides the only campground available in the low country and also heads three major trails. Frijole Ranger-Information Station, located on highway 62-180, is also a popular area which most users visit. The road leading to Frijole Ranch House, and the trail to Smith and Manzanita Springs, begin at the ranger station. In addition to these roads, an asphalt road and parking facility provide excellent access to the trail head at the mouth of McKittrick Canyon.

Those entry areas which receive limited use due to poor roads, roads under construction, or limited publicity are: West and Upper Dog Canyons, Old Guadalupe Peak Trail, Williams Ranch, and North McKittrick Canyon Trail. These trail heads have a significant impact on the park, regardless of their limited use. Trails, roads, and parking areas are in most instances created by simply removing the vegetation, which subsequently increases run-off, accelerates erosion, and in many cases degrades water quality.

Throughout the park many changes are taking place, some are natural and others are the result of man's use and management of the park. Usually most of man's impacts are considered as negative when preservation of a natural ecosystem is a goal. However, in many areas, which were impacted by man's prior use of the park, park management has improved natural conditions tremendously. Areas once overgrazed by herds of goats and cattle are recovering and now provide forage for deer, elk, and other smaller wildlife; which surveys have shown increase the satisfaction of the recreational experience (Marlett and Mertes, 1978).

Management of an area such as the Guadalupe Mountains, for the purpose of preserving the natural ecosystems and to provide for recreation and the enjoyment of those same ecosystems, is a difficult and most often compromising task. As long as man has occupied the Guadalupes he has had an impact. So long as people visit the park there will continue to be impacts. Hopefully through proper design and development of access, facilities, circulation, and educational media, future impacts can be limited within the constraints of natural capabilities and carrying capacities.

# CHAPTER III WATERSHED INVENTORY STUDIES

One of the initial steps in the management planning process for Guadalupe Mountains National Park was to undertake a series of studies to inventory biophysical and cultural resources of the park in order to establish certain baseline data conditions. Initial investigations highlighted the importance of water in this semi-arid region.

> Water is a critical factor which will strongly influence how the park is used. There are few dependable springs, several of which flow into North and South McKittrick Canyons. The park's limited riparian vegetation and aquatic habitat could be jeopardized by diversion of these springs for other purposes. Within North and South McKittrick Canyons, several compact and easily damaged relict communities exist. Because of the small number of permanent streams in the area, the aquatic habitat which these few do provide is especially important. (National Park Service, 1973)

As a result of recommendations for further research prior to the development of final management plans, studies were undertaken to delineate the major drainage basins which headwater within the park and to characterize these watersheds in terms of certain variables which would affect the hydrologic response of the basins. A second objective was to compare data from the various watersheds in an effort to evaluate similarities among the individual basins. Based upon this analysis a limited number of watersheds were selected for more intensive investigation and instrumentation.

To fully understand the water component one must have some knowledge of the way in which water is generated within and moves through a natural landscape system. The unique functional response unit which permits study of the water component in a natural environment is the catchment basin or watershed, and it is this unit's physical, biological, and cultural parameters which affect its hydrologic response characteristics.

The description of drainage basin characteristics and stream channel networks has evolved from a qualitative study to a quantitative analysis in recent years (Branson, et al., 1972). Horton (1945) was the pioneer of these systematic studies, and more recently, Strahler (1954) and his students have expanded on Horton's work. These quantitative variables have been the basis for interbasin comparisons and evaluation of hydrographic responses.

## DATA COLLECTION

Major watershed boundaries of basins whose headwaters originate within the park were delineated on five United States Geological Survey 7-1/2 minute quadrangle maps. Due to the nonexistence of United States Geological Survey 7-1/2 minute quadrangle maps of the North McKittrick Canyon area in New Mexico, color aerial photographs at a scale of 1:114,700 were used for delineation of watersheds. Watershed boundaries and stream channels were delineated by stereoscopic analysis of the photographs. The watershed and channel delineations for the area north of the park boundary were then enlarged to a scale of 1:24,000.

Once each of the basins had been delineated, as well as the channels within the basins, the following hydrologic variables were measured.

## AREAL EXTENT

One of the easiest physical hydrologic characteristics to measure is the areal extent of a particular watershed. The size or area of a drainage basin is an important consideration in that the total volume of water is directly related to the size of the basin. Generally, large watersheds have greater runoff than small watersheds (Anderson, 1957). However, the runoff per unit of area decreases as the area of the watershed increases (Schumm and Hadley, 1961).

Another important consideration is the effect of watershed area on peak flows. As is the case with total water yields, higher peak flows are usually associated with larger areas. However, when such outputs are expressed in terms of flow per unit of watershed area, it is the smaller watersheds that characteristically have the greatest rates of flow (Avery, 1975).

The area, in square miles, was determined for each major watershed unit by use of a planimeter.

## SHAPE COEFFICIENTS

The outline form or shape of a watershed strongly influences its hydrographic patterns. Although watershed shape is difficult to quantify, several different indices comparing the configurations of different watersheds have been proposed. Two of these methods quantitatively express the compactness or degree of circularity of a basin's form.

Gravelius' Compactness Coefficient (Gravelius, 1914) may be computed by the following:

$$Si = \frac{0.282\ (P)}{A}$$

Where Si = compactness coefficient shape index
P = perimeter of the basin in miles
A = basin area in square miles.

When a watershed is a perfect circle it will have an index of 1. The closer the shape index is to 1, the greater the likelihood that precipitation will be quickly concentrated in the main channel, resulting in rapid peak flows (Avery, 1975).

Miller's Circularity Ratio (Miller, et al., 1964) expresses the departure from circularity of a watershed and is expressed in terms of a ratio as follows:

$$Rc = \frac{A}{0.0796\ (P^2)}$$

Where Rc = circularity ratio
A = basin area in square miles
P = perimeter of the basin in miles

In this instance, a perfect circle would have a circularity ratio of 1 and all others would have a ratio of less than 1 (Chorley, 1969; Branson, et al., 1972).

Both of these shape coefficients express quantitatively that circular watersheds have high runoff and low sediment yields. This relationship can be explained by the fact that circular watersheds concentrate water faster and runoff travels shorter distances, allowing for less evaporation and less opportunity for channel storage. However, long narrow watersheds tend to have steep slopes with consequently higher overland velocities and sediment transport capacities (Branson, et al., 1972).

## BASIN PERIMETER

Basin perimeter is considered to be another important variable as it relates to both shape and to areal extent of the watershed.

Each of the major watersheds was measured for the length of the perimeter of the basin, in miles.

## DRAINAGE NETWORK

The pattern or arrangement of natural streams in a watershed is another important physical characteristic for two reasons. First, they provide evidence of the efficiency of the drainage system and therefore its hydrologic pattern. Second, as Horton (1933) points out, "It is an excellent indicator of soil permeability."

Three such indices are useful in determining the pattern of natural streams. Drainage density (Branson, et al., 1972) is determined by the following formula:

$$Dd = \frac{L}{A}$$

Where $Dd$ = drainage density
$L$ = length of streams in miles
$A$ = basin area in square miles

Drainage density is an expression of the closeness of spacing of stream channels in a watershed. In general, low drainage densities are indicative of regions of highly permeable subsoils, dense vegetative cover, and low relief (Avery, 1975). Schumm and Hadley (1961) indicate that when drainage density is plotted against mean annual runoff, the results suggest that drainage density, if not dependent simply on runoff, is at least dependent upon the same variables that influence runoff.

Stream channel lengths by stream order were obtained from United States Geological Survey 7-1/2 minute quadrangle maps with a map measure wheel.

A second index is a quantitative approach to classifying streams in a basin. This classification is a systematic ordering of the branches of a stream network. Although a method was proposed by Gravelius in 1914, since that time, a variety of ordering systems has been advocated and used. According to Gregory and Walling (1973), the Strahler (1964) modification of Horton's method (1945) has been used most extensively.

Stream order was determined by using the procedure outlined by Strahler (1964). Essentially the designation process delineates each nonbranching tributary regardless of where it joins the drainage network as a Class 1 stream. Streams receiving only Class 1 channels are designated Class 2. Third order channels result from the confluence of two second order channels and similarly for higher orders. The channel order value at the basin outlet indicates the size and extent of branching of the basin drainage network.

The third index is a qualitative classification of the overall drainage pattern. These classification systems have been described by numerous people; Gregory and Walling (1973), Avery (1968), Small (1970), and Leuder (1959). The system described by sample illustration in Avery (1968) covers six basic types of patterns without becoming too cumbersome in terms of number of discrete patterns. This system was used to visually classify the various watershed drainage patterns as dendritic, parallel, rectangular, centripetal, radial, or trellis.

## CHANNEL PROFILES

Slope and elevation are also important hydrologic characteristics. The slope of a watershed channel, expressed in the number of feet of elevation drop per mile of stream channel, greatly influences the velocity and therefore the erosion potential of stream flow. Slope is also related to infiltration, evapotranspiration, soil moisture, and groundwater contribution to stream flow. The variations in elevation of a watershed are important factors with respect to temperature and precipitation patterns, especially in mountainous topography (Avery, 1975).

Channel profiles of the major stream within each watershed were determined using map data. Measurements were made from the ridge line nearest the longest channel with the highest elevation. Distances along the major stream channel were measured with a map measure wheel at two hundred foot contours and at the terminus with the elevations noted.

## MAJOR VEGETATIVE COMMUNITIES

The type, distribution, and quantity of vegetation is a major controlling factor in the development of a drainage basin and the erosional processes involved. When vegetational cover is dense, the erosional processes acting on the soil surface are far less effective than in areas where vegetation is sparse and the soil is exposed to erosion (Branson, et al., 1972).

Major vegetative communities within Guadalupe Mountains National Park were initially determined from an existing interagency browse survey map supplied by the National Park Service. This map was enlarged to a scale of 1:24,000 to enable compatibility with the watershed boundaries map. Each vegetative community was measured and percent composition of each type within each watershed was determined.

## MAJOR GEOLOGIC PARENT MATERIALS

A complete description of the characteristics of a watershed must include reference to geologic parent material of the unit. This is necessary because the type of rock underlying the unit will have a marked effect on the nature and extent of groundwater storage and will also determine the type of material which is available for erosion and transport within the unit as well as the nature of the soil present in the unit (Gregory and Walling, 1973).

Major geologic parent material boundaries within Guadalupe Mountains National Park were determined from an existing geologic map (Goolsby, 1974). This map was enlarged to a scale of 1:24,000 to facilitate an overlay of the watershed boundaries map. Each geologic unit was measured and percentages of each unit within each watershed were determined.

## LAND FORM

The gross form of a watershed unit can be expressed in terms of slope gradients. Slope gradients within Guadalupe Mountains National Park were obtained from United States Geological Survey maps using a procedure described by Raisz and Henry (1934). This procedure determined the slope gradient of the land by measuring the contour spacing on topographic maps. Three slope gradient units were identified and measured: slopes less than five percent, slopes between five percent and fifty percent, and greater than fifty percent. Percentages of each slope gradient class within each watershed were determined.

## DATA ANALYSIS

Each of these hydrologic characteristics in its own way influences the hydrographic pattern of a watershed. Therefore, a comparison of each of these characteristics for each watershed can provide a quantitative basis for an interbasin similarity analysis.

Computer programs were developed to expedite the analysis and comparison of quantitative data between major watersheds. The programs compared all quantitative variables for each major watershed, "base watershed," to all other major watersheds in the park. A difference comparison determined the deviation, represented as the percent of the compared watershed from the "base watershed" for each variable. The deviations were then totaled for each watershed pair and divided by the total number of variables compared. The resulting difference index, with values ranging from 0.0 to 1.0, then made it possible to determine which watershed pairs are similar in relation to all of the measured variables. A difference index of 0.0 indicates that the watersheds were identical with respect to the measured variables, while a difference index value of 1.0 implies total dissimilarity.

## RESULTS AND DISCUSSION

On a regional scale the Guadalupe Mountains National Park contains headwater areas of essentially two distinct surface water drainage systems. The north, northwest, west, southwest and southern portions of the park drain by various routes into a closed basin west of the park known as Crow Flats in the immediate vicinity of the Park or as the Salt Flats Basin on a larger scale. There are no external surface outlets to the basin and dry, salt lake accumulations generally high in gypsum are a common feature. The remainder of the park drains via Delaware Creek and Black River to the Pecos River and ultimately to the Rio Grande River and the Gulf of Mexico.

Delineation of major watersheds originating within Guadalupe Mountains National Park resulted in the identification of thirty-five distinct drainage basins (Figure 10). Areal extent of the basins ranged from 0.15 square miles for watershed 8B to 25.32 square miles for watershed 6 (Table 2). The average size of the watersheds studied was 3.84 square miles. Gravelius' Compactness Coefficient values varied from 1.11 for watershed 2A to 2.19 for watershed 8D. The average value for the compactness coefficient was 1.53. Miller's Circularity Ratio values ranged from 0.21 for watershed 8D to 0.82 for watershed 2A. The average circularity ratio value was 0.47. Perimeter measurements for all major watersheds varied from 2.46 for watershed 8B to 29.68 miles for watershed 6. The average perimeter value was 9.26 miles. Drainage densities varied from 3.61 miles of stream channel per square mile of area for watershed 9D to 10.32 miles of stream channel per square mile of area for watershed 9C. The average drainage density was 6.73. The calculations for drainage density required that the stream channel lengths be measured. These measurements by stream order are presented in Table 3. Stream orders at the basin outlet vary from 2nd order for watersheds 8A1, 8B, 8D, and 10B3 to a 6th order for watershed 6. The drainage pattern exhibited by the major watersheds revealed that the majority of the basins (23) exhibited a parallel drainage pattern, while ten were dendritic, and only two exhibited an overall rectangular pattern.

Maximum elevations for the watersheds varied from 4,130 feet for watershed 10B3 to 8,749 feet for watershed 9A. The average maximum elevation was 7,174 feet. Minimum elevations for the watersheds varied from 3,670 feet for watershed 10C1 to 5,950 feet for watershed 2A. The average minimum elevation was 4,544 feet. Main channel lengths varied

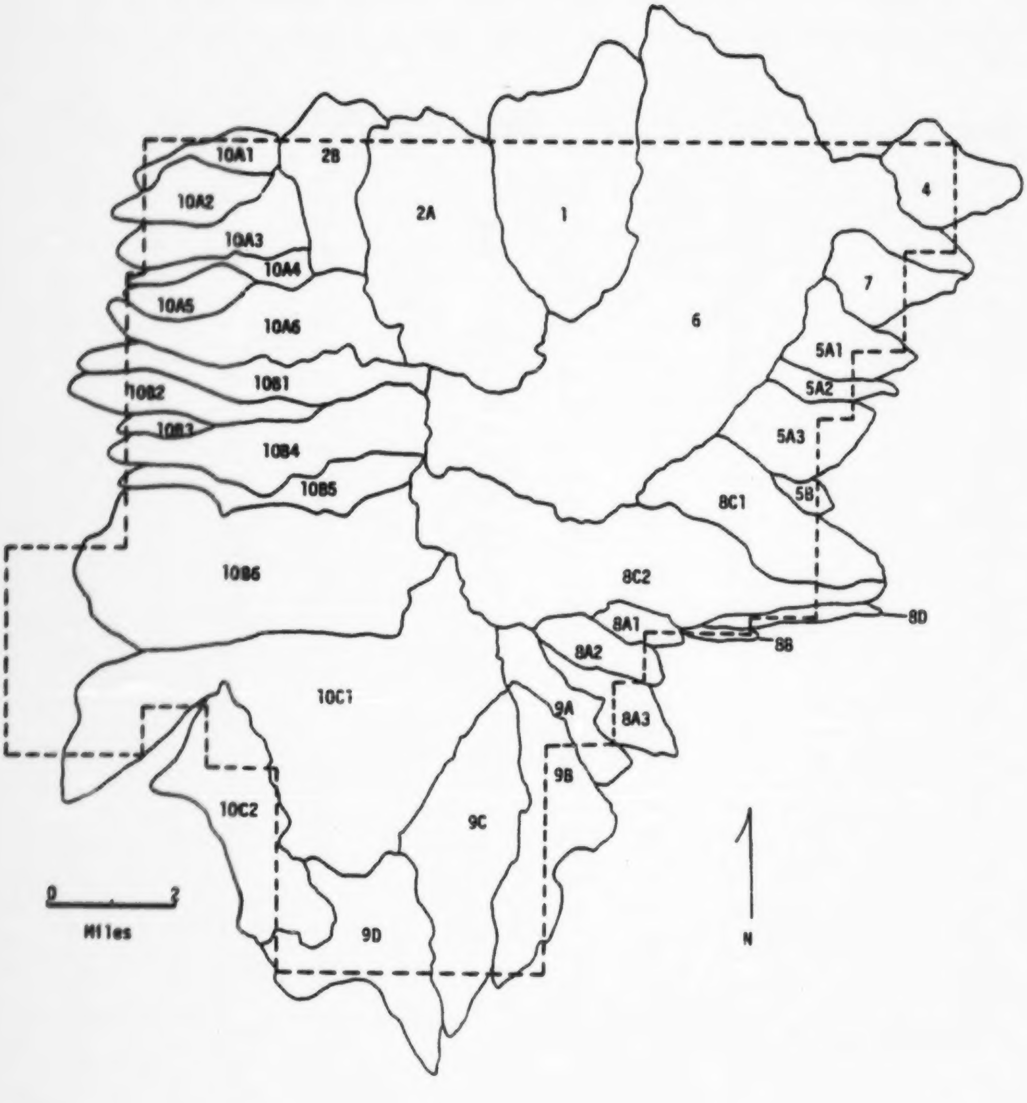

Figure 10. Watershed Delineations.

## TABLE 2. HYDROLOGIC CHARACTERISTICS OF WATERSHEDS

| | Variables | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Area (Sq.mi.) | Perimeter (Mi.) | Compactness Coefficient | Circularity Ratio | Maximum Elev. (Ft.) | Minimum Elev. (Ft.) | Channel Length (Mi.) | Mean Channel Slope (Ft/mi) | Drainage Density | Stream Order | Drainage Pattern * |
| 1 | 7.23 | 11.48 | 1.20 | 0.69 | 7780 | 5840 | 5.16 | 367 | 4.66 | 4 | R |
| 2A | 8.57 | 11.48 | 1.11 | 0.82 | 8180 | 5950 | 5.19 | 430 | 5.43 | 4 | D |
| 2B | 2.88 | 8.14 | 1.36 | 0.54 | 6820 | 5840 | 3.31 | 298 | 5.58 | 4 | D |
| 4 | 2.18 | 6.06 | 1.16 | 0.76 | 7060 | 4895 | 2.76 | 784 | 4.78 | 3 | P |
| 5A1 | 1.69 | 5.78 | 1.25 | 0.64 | 7520 | 5040 | 2.20 | 1127 | 8.49 | 4 | P |
| 5A2 | 0.62 | 4.53 | 1.62 | 0.38 | 7720 | 5130 | 2.13 | 1216 | 8.84 | 3 | P |
| 5A3 | 2.27 | 6.19 | 1.16 | 0.74 | 8160 | 5110 | 3.04 | 1003 | 6.79 | 4 | P |
| 5B | 0.33 | 2.57 | 1.26 | 0.63 | 6000 | 5180 | 1.10 | 745 | 5.88 | 3 | P |
| 6 | 25.32 | 29.68 | 1.66 | 0.36 | 8480 | 4900 | 14.69 | 244 | 5.75 | 6 | R |
| 7 | 1.68 | 5.88 | 1.27 | 0.62 | 6985 | 4800 | 2.56 | 814 | 6.23 | 3 | P |
| 8A1 | 0.61 | 3.46 | 1.25 | 0.64 | 6850 | 5560 | 1.50 | 684 | 5.51 | 2 | P |
| 8A2 | 1.18 | 4.98 | 1.29 | 0.60 | 8080 | 5465 | 2.23 | 1173 | 7.98 | 4 | P |
| 8A3 | 1.38 | 6.38 | 1.53 | 0.43 | 7440 | 5320 | 3.00 | 707 | 7.75 | 4 | D |
| 8B | 0.15 | 2.46 | 1.79 | 0.39 | 5570 | 5300 | 1.10 | 285 | 9.93 | 2 | P |
| 8C1 | 3.85 | 9.71 | 1.40 | 0.51 | 8220 | 4980 | 4.27 | 766 | 7.00 | 4 | P |
| 8C2 | 9.07 | 18.41 | 1.72 | 0.34 | 8610 | 4860 | 8.30 | 383 | 7.29 | 4 | D |
| 8D | 0.54 | 5.70 | 2.19 | 0.21 | 5495 | 5025 | 2.78 | 169 | 5.91 | 2 | P |
| 9A | 1.68 | 7.49 | 1.63 | 0.38 | 8749 | 4980 | 3.21 | 1159 | 8.03 | 4 | D |
| 9B | 4.09 | 11.68 | 1.63 | 0.38 | 8040 | 4210 | 5.91 | 648 | 9.13 | 4 | D |
| 9C | 5.59 | 12.28 | 1.46 | 0.47 | 8020 | 4145 | 6.23 | 622 | 10.32 | 5 | D |
| 9D | 4.41 | 12.36 | 1.66 | 0.36 | 4980 | 4040 | 4.20 | 224 | 3.61 | 3 | D |
| 10A1 | 0.92 | 5.58 | 1.63 | 0.37 | 6580 | 3840 | 2.37 | 1282 | 6.17 | 3 | P |
| 10A2 | 1.54 | 5.75 | 1.31 | 0.59 | 6820 | 3710 | 2.62 | 1073 | 7.28 | 4 | P |
| 10A3 | 2.12 | 7.79 | 1.51 | 0.44 | 6100 | 3700 | 3.48 | 920 | 6.65 | 3 | P |
| 10A4 | 0.87 | 6.56 | 1.98 | 0.25 | 6830 | 3725 | 2.91 | 1087 | 5.47 | 3 | P |
| 10A5 | 1.03 | 4.66 | 1.29 | 0.60 | 5490 | 3730 | 2.43 | 724 | 7.17 | 3 | P |
| 10A6 | 3.89 | 11.64 | 1.66 | 0.36 | 7680 | 3705 | 5.21 | 763 | 6.44 | 4 | D |
| 10B1 | 2.64 | 12.08 | 2.10 | 0.23 | 8000 | 3700 | 5.78 | 744 | 6.58 | 4 | D |
| 10B2 | 1.72 | 8.23 | 1.79 | 0.31 | 5675 | 3700 | 4.26 | 462 | 6.34 | 3 | P |
| 10B3 | 0.41 | 3.31 | 1.48 | 0.47 | 4130 | 3770 | 1.54 | 234 | 7.60 | 2 | P |
| 10B4 | 3.97 | 11.66 | 1.65 | 0.37 | 8580 | 3775 | 5.27 | 912 | 5.81 | 4 | P |
| 10B5 | 1.98 | 10.67 | 2.14 | 0.22 | 6420 | 3750 | 5.23 | 893 | 5.88 | 3 | P |
| 10B6 | 10.96 | 15.15 | 1.29 | 0.60 | 8420 | 3710 | 6.7 | 702 | 6.01 | 4 | P |
| 10C1 | 15.27 | 22.67 | 1.64 | 0.37 | 8440 | 3670 | 8.68 | 551 | 6.54 | 5 | P |
| 10C2 | 4.54 | 11.65 | 1.54 | 0.42 | 4800 | 3735 | 3.52 | 303 | 5.14 | 3 | P |

* P= Parallel, D= Dendritic, R= Rectangular

## TABLE 3. MILES OF CHANNEL LENGTH BY STREAM ORDER

| Watershed | 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|---|
| 1 | 21.10 | 5.98 | 5.62 | 2.37 | | | 35.07 |
| 2A | 28.44 | 9.03 | 6.53 | 2.52 | | | 46.52 |
| 2B | 9.73 | 2.78 | 3.14 | 0.18 | | | 15.83 |
| 4 | 4.12 | 5.19 | 1.12 | | | | 10.43 |
| 5A1 | 9.41 | 2.33 | 2.52 | 0.08 | | | 14.34 |
| 5A2 | 2.70 | 2.70 | 0.08 | | | | 5.48 |
| 5A3 | 10.39 | 2.91 | 2.05 | 0.07 | | | 15.42 |
| 5B | 1.48 | 0.20 | 0.25 | | | | 1.93 |
| 6 | 90.43 | 19.54 | 15.96 | 10.38 | 5.74 | 3.54 | 145.59 |
| 7 | 6.03 | 3.33 | 1.11 | | | | 10.47 |
| 8A1 | 2.39 | 0.97 | | | | | 3.36 |
| 8A2 | 5.60 | 2.07 | 1.66 | 0.06 | | | 9.39 |
| 8A3 | 6.37 | 1.39 | 2.75 | 0.18 | | | 10.69 |
| 8B | 0.84 | 0.65 | | | | | 1.49 |
| 8C1 | 15.63 | 5.73 | 3.93 | 1.66 | | | 26.95 |
| 8C2 | 39.41 | 13.21 | 3.97 | 9.53 | | | 66.12 |
| 8D | 2.50 | 0.69 | | | | | 3.19 |
| 9A | 9.23 | 2.31 | 2.23 | 1.06 | | | 14.83 |
| 9B | 19.32 | 9.16 | 5.02 | 3.84 | | | 37.34 |
| 9C | 30.93 | 11.85 | 6.47 | 5.70 | 2.72 | | 57.67 |
| 9D | 9.50 | 4.70 | 1.70 | | | | 15.90 |
| 10A1 | 1.81 | 2.07 | 1.80 | | | | 5.68 |
| 10A2 | 7.22 | 2.84 | 1.08 | 0.07 | | | 11.21 |
| 10A3 | 8.08 | 3.27 | 2.75 | | | | 14.10 |
| 10A4 | 1.53 | 0.31 | 2.92 | | | | 4.76 |
| 10A5 | 5.01 | 1.68 | 0.69 | | | | 7.38 |
| 10A6 | 15.28 | 4.05 | 5.01 | 0.71 | | | 25.05 |
| 10B1 | 9.05 | 3.78 | 4.38 | 0.17 | | | 17.38 |
| 10B2 | 5.69 | 5.04 | 0.18 | | | | 10.91 |
| 10B3 | 2.69 | 0.46 | | | | | 3.15 |
| 10B4 | 15.84 | 2.95 | 2.73 | 5.50 | | | 27.02 |
| 10B5 | 5.11 | 1.63 | 4.24 | | | | 10.98 |
| 10B6 | 31.74 | 13.12 | 12.81 | 8.24 | | | 65.91 |
| 10C1 | 51.66 | 14.35 | 18.08 | 6.85 | 8.89 | | 99.83 |
| 10C2 | 16.50 | 5.85 | 1.00 | | | | 23.35 |

from 1.10 miles for watersheds 5B and 8D to 14.69 miles for watershed 6. Average main channel length was 4.12 miles. Mean channel slope varied from 169 feet per mile for watershed 8D to 1,282 feet per mile for watershed 10A1. The average mean channel slope was 697 feet per mile.

A total of sixty-five vegetative communities were described according to primary and secondary species. The composition of each watershed by vegetative communities is presented in Table 4. (Fuller, 1976, contains complete descriptions of vegetative communities and geologic parent materials.) A total of eight geologic parent materials were described and measured. The composition of each watershed by geologic parent materials is presented in Table 5. Three slope gradients--less than five percent, between five percent and fifty percent, and greater than fifty percent--were measured. The composition of each watershed by slope gradients is presented in Table 6.

All possible pairings of watersheds (595) were compared using eleven quantitative variables to produce indices of similarity. The thirty most similar watershed pairs, approximately five percent of all comparisons, from this analysis are presented in Table 7. Figure 11 graphically portrays the clusters of similar watershed units developed from these "most similar pairs" of watershed units.

The selection of watersheds for further intensive investigation was undertaken on the basis of the similarity analysis clusters and in consultation with Park Service management and research personnel. Additional factors considered in the selection process were accessibility, geographical distribution, and anticipated recreational user impact patterns. As a result of these discussions watersheds 1, 6, 7, 8B, 8D, and 10A6 were selected for further study.

# TABLE 4. PERCENT COMPOSITION BY VEGETATIVE COMMUNITIES

Vegetative Communities

| | 1 | | 3 | | 5 | | | | | | | | | | | | | | | | | | | | | | | 6 | | | | 8 | 9 | | | 10 | | 11 | | | | | | | | 12 | 13 | 16 | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | A | B | A | B | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | A | B | C | D | A | A | B | C | A | B | A | B | C | D | E | F | G | H | A | A | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | R | S |
| 1 | - | - | - | - | 6 | 27 | - | - | 7 | - | - | - | - | - | - | - | 16 | - | 2 | 5 | - | - | 2 | 6 | 12 | 3 | - | 6 | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2A | - | - | - | 6 | - | 1 | - | 11 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | 50 | 1 | - | - | - | 6 | - | 4 | - | - | - | 17 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2B | - | - | - | - | 23 | - | - | 13 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 52 | - | - | - | - | - | - | - | - | - | 4 | 8 | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 25 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 75 | - |
| 5A1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 56 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 42 | - |
| 5A2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 37 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 28 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 35 | - |
| 5A3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 31 | - | 1 | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 33 | - | - | - | - | - | 14 | - | - | - | - | - | - | - | - | - | 15 | - | - |
| 5B | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 91 | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| 6 | - | 1 | - | - | - | - | - | - | - | - | 1 | - | 6 | - | - | - | - | - | 21 | 1 | - | - | 1 | 20 | - | - | 3 | 27 | 2 | 9 | 1 | - | - | 2 | 3 | T | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 |
| 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 33 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 49 | 18 |
| 8A1 | 49 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 16 | 35 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8A2 | 34 | - | 25 | - | - | - | - | - | - | - | - | - | - | - | 17 | - | 12 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 12 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8A3 | - | - | 11 | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 29 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 57 | - | - | - |
| 8B | 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 34 | 52 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8C1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 85 | - | 12 | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8C2 | - | - | - | - | - | - | - | - | - | - | - | - | 23 | - | 3 | - | 2 | 7 | 39 | T | 4 | - | - | - | - | - | - | T | 17 | - | - | T | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 8D | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 29 | 71 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 9A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 27 | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 34 | - | - | - | 15 | - | - | - | - | - | - | - | - | 10 | 10 | - | - | - | - |
| 9B | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 25 | 11 | - | 37 | - | 4 | 5 | - | - | - | - | - | - | 9 | - | - | - | - | - | - | - | - | 6 | - | - | - | - | - |
| 9C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | 23 | 1 | 13 | 8 | 16 | 23 | - | - | 7 | - | - | - | - | - | - | - | - | 2 | T | - | - | - | - | - | - | - | - |
| 9D | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 49 | 30 | - | - | - | - | T | - | - | 1 | - | - | - | 17 | - | 2 | - | - | - | 1 | - | - | - | - | - | - | - | - |
| 10A1 | - | - | - | - | 9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 49 | 23 | 19 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10A2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 14 | 30 | 56 | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - |
| 10A3 | - | - | - | - | 19 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 31 | 7 | 41 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10A4 | - | - | - | - | 20 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 33 | 9 | 37 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10A5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 11 | 23 | 66 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10A6 | - | - | - | - | 3 | 10 | 8 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 11 | T | - | - | - | - | - | 5 | - | - | - | - | - | - | - | 15 | 14 | 22 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10B1 | - | - | - | - | 16 | 4 | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - | 1 | - | - | - | - | - | 16 | - | - | - | - | - | - | - | 26 | 32 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10B2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 21 | - | - | - | - | - | - | - | 11 | 68 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10B3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 13 | - | - | - | - | - | - | - | - | 87 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10B4 | - | - | - | - | - | 17 | - | - | - | 12 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 5 | - | 1 | - | - | - | - | - | 24 | - | - | - | - | - | - | - | 11 | 12 | - | 8 | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10B5 | - | - | - | - | - | 6 | - | - | - | 8 | - | - | 1 | 23 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 3 | - | T | - | - | - | - | - | 14 | - | - | - | - | - | - | - | 4 | 19 | - | 19 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10B6 | - | - | - | - | - | 2 | - | - | - | 3 | - | - | T | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | T | - | - | 1 | - | - | - | - | - | 6 | 17 | 15 | 2 | - | - | - | - | 1 | 2 | 6 | 26 | - | - | 10 | 3 | 1 | 2 | 1 | - | - | - | - | - | - | - | - | - | - |
| 10C1 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 2 | - | - | - | - | - | 12 | 30 | 4 | 5 | 1 | 4 | - | - | 1 | - | 3 | - | - | - | 3 | 11 | 9 | - | - | 1 | 4 | 1 | 1 | - | - | - | - | - | - |
| 10C2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 16 | | - | - | - | - | - | - | - | - | | - | - | 36 | - | 16 | - | - | - | - | - | 30 | - | - | - | - | - | - |

# TABLE 5. PERCENT COMPOSITION BY GEOLOGIC PARENT MATERIALS

|  | Geologic Parent Materials |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Watershed | MI | QCFL | TI | SS | QC | SL | SH | QR |
| 1 | 5 | - | 86 | 6 | 3 | - | - | - |
| 2A | 19 | 6 | 67 | 8 | - | - | - | - |
| 2B | 60 | - | 38 | 2 | - | - | - | - |
| 4 | 45 | 7 | 39 | - | 9 | - | - | - |
| 5A1 | 53 | - | - | 2 | 35 | 10 | - | - |
| 5A2 | 51 | - | 2 | - | 25 | 22 | - | - |
| 5A3 | 33 | - | 26 | 10 | 11 | 20 | - | - |
| 5B | - | - | 20 | 16 | 10 | 54 | - | - |
| 6 | 60 | 1 | 36 | 3 | T | - | - | - |
| 7 | 40 | 1 | 29 | 14 | 16 | - | - | - |
| 8A1 | 1 | 3 | 24 | 37 | 27 | 8 | - | - |
| 8A2 | 38 | 38 | 3 | 10 | - | 11 | - | - |
| 8A3 | 7 | 20 | 16 | 52 | T | 5 | - | - |
| 8B | - | - | 6 | - | 94 | - | - | - |
| 8C1 | 26 | - | 9 | 16 | 36 | 13 | - | - |
| 8C2 | 49 | - | 1 | 1 | 35 | 14 | - | - |
| 8D | - | - | - | - | 100 | - | - | - |
| 9A | 28 | - | 16 | 42 | 2 | 12 | - | - |
| 9B | T | 38 | 12 | 37 | 7 | 1 | 5 | - |
| 9C | 12 | 45 | 9 | 9 | 14 | 11 | T | - |
| 9D | 36 | 43 | - | - | 21 | - | - | - |
| 10A1 | 38 | 18 | 1 | 17 | 6 | - | 20 | - |
| 10A2 | 28 | 45 | - | 14 | - | - | 13 | - |
| 10A3 | 35 | 38 | 6 | 10 | 3 | - | 8 | - |
| 10A4 | 20 | 39 | 21 | 10 | 2 | - | 8 | - |
| 10A5 | 16 | 73 | - | 1 | - | - | 10 | - |
| 10A6 | 37 | 29 | 15 | 12 | - | - | 7 | - |
| 10B1 | 39 | 42 | 6 | 10 | - | - | 3 | - |
| 10B2 | 13 | 84 | - | - | 1 | - | 2 | - |
| 10B3 | - | 100 | - | - | - | - | - | - |
| 10B4 | 39 | 40 | 7 | 8 | T | - | 5 | 1 |
| 10B5 | 46 | 34 | 11 | 5 | - | - | 4 | - |
| 10B6 | 16 | 71 | 6 | 4 | 2 | T | T | T |
| 10C1 | 20 | 61 | 4 | 8 | 4 | 2 | - | 1 |
| 10C2 | 68 | 30 | 2 | - | - | - | - | - |

## TABLE 6. PERCENT COMPOSITION BY SLOPE GRADIENTS

| | Slope Gradients | | |
|---|---|---|---|
| Watershed | Less than 5% | Between 5%-50% | Greater than 50% |
| 1 | - | 63 | 37 |
| 2A | 2 | 77 | 21 |
| 2B | 3 | 87 | 10 |
| 4 | - | 66 | 34 |
| 5A1 | - | 52 | 48 |
| 5A2 | - | 50 | 40 |
| 5A3 | - | 45 | 55 |
| 5B | 3 | 89 | 8 |
| 6 | T | 41 | 59 |
| 7 | - | 60 | 40 |
| 8A1 | - | 95 | 5 |
| 8A2 | - | 61 | 39 |
| 8A3 | - | 87 | 13 |
| 8B | 100 | - | - |
| 8C1 | 21 | 45 | 34 |
| 8C2 | 12 | 52 | 36 |
| 8D | 100 | - | - |
| 9A | - | 49 | 51 |
| 9B | 28 | 53 | 19 |
| 9C | 32 | 50 | 18 |
| 9D | 40 | 34 | 26 |
| 10A1 | - | 53 | 47 |
| 10A2 | 13 | 54 | 33 |
| 10A3 | 9 | 50 | 41 |
| 10A4 | 8 | 47 | 45 |
| 10A5 | 22 | 65 | 13 |
| 10A6 | 11 | 51 | 38 |
| 10B1 | 18 | 43 | 39 |
| 10B2 | 32 | 66 | 2 |
| 10B3 | 52 | 48 | - |
| 10B4 | 11 | 46 | 43 |
| 10B5 | 18 | 43 | 39 |
| 10B6 | 42 | 44 | 14 |
| 10C1 | 38 | 37 | 25 |
| 10C2 | 23 | 24 | 53 |

## TABLE 7. MOST SIMILAR WATERSHED PAIRS BY HYDROLOGIC VARIABLES

| Watershed Pair | Similarity Index |
|---|---|
| 4 - 7 | 0.1385 |
| 10A3 - 10A4 | 0.1464 |
| 10A6 - 10B4 | 0.1568 |
| 10A2 - 10A5 | 0.1663 |
| 10B1 - 10B5 | 0.1691 |
| 5A1 - 5A2 | 0.1702 |
| 5A1 - 7 | 0.1770 |
| 10A2 - 10A3 | 0.1861 |
| 10A6 - 10B1 | 0.1916 |
| 10A1 - 10A4 | 0.1964 |
| 10B4 - 10B5 | 0.2019 |
| 10B1 - 10B4 | 0.2030 |
| 10A3 - 10A6 | 0.2103 |
| 9B - 9C | 0.2124 |
| 10A1 - 10A3 | 0.2211 |
| 10A2 - 10A4 | 0.2211 |
| 10A1 - 10A2 | 0.2233 |
| 10A3 - 10B1 | 0.2237 |
| 10B6 - 10C1 | 0.2332 |
| 8B - 8D | 0.2377 |
| 10A6 - 10B5 | 0.2394 |
| 1 - 2A | 0.2405 |
| 5A3 - 7 | 0.2415 |
| 4 - 5A1 | 0.2464 |
| 10A3 - 10B4 | 0.2532 |
| 5A2 - 7 | 0.2594 |
| 5A3 - 9A | 0.2609 |
| 5A1 - 5A3 | 0.2676 |
| 4 - 5A3 | 0.2677 |
| 2A - 2B | 0.2746 |

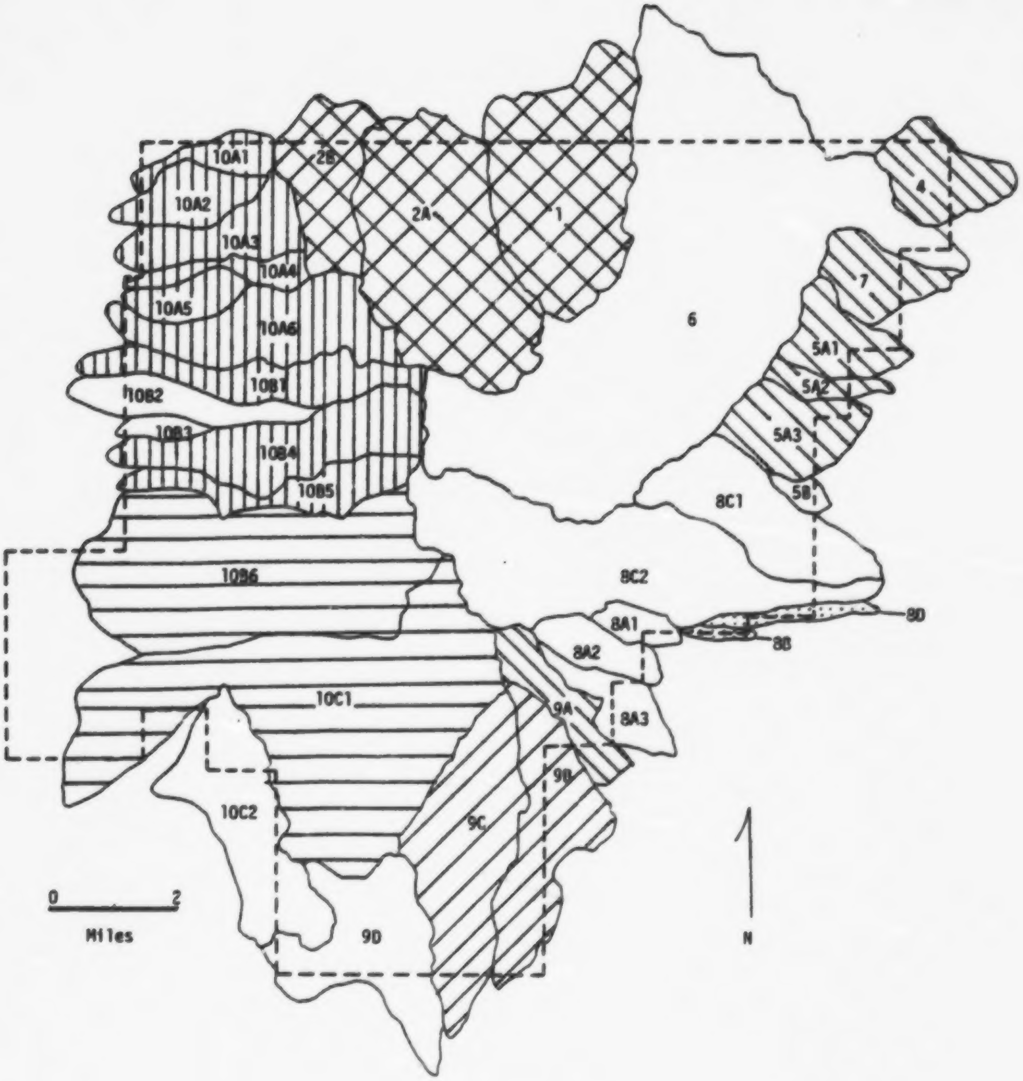

Figure 11. Watershed Clusters.

# CHAPTER IV GEOLOGIC CONSIDERATIONS*

## INTRODUCTION

The Guadalupe Mountains National Park contains a portion of the southern end of the Guadalupe Mountains, and includes a number of the highest peaks in Texas. The mountain mass of the study area is the northern half of an eastward-tilted block more than 100 miles long and 50 miles wide. Mountains extend both northward and southward from the Park site, and the study area is immediately adjacent to and includes part of the Delaware Basin. The magnificent geologic features, which were a major factor for the inclusion of the area in the National Park System, have been formed by the combined processes of faulting, tectonic (mountain building) activity, and reef building.

There are few evidences of geologic observation of the Guadalupe Mountains prior to 1854, when Captain John Pope surveyed through Guadalupe Pass during an attempt to locate a practical railroad route to the Pacific Coast. The following year, Pope was accompanied on another expedition by Dr. G.G. Shumard, a noted western geologist (Shumard, 1858). The next geologic information was gathered by R.S. Tarr (1892) in 1890, followed by G.H. Girty (1908), and G.B. Richardson (1904) of the United States Geological Survey in 1901 and 1903. Subsequent investigations are noted in the list of references.

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* Portions of this chapter--quote, paraphrase, and otherwise follow closely the definitive works on the region by Newell, et al., 1953; P.B. King, 1948; and P.T. Hayes, 1964.

One of the more colorful physical descriptions of the region is drawn from P.B. King (1948):

> [From the top of Guadalupe Peak] . . . the contrast that it reveals between the country to the east and to the west. Eastward the mountains descend in a long slope to the Pecos River, 50 miles away, whose valley may be seen as a dark band in the distance. On the skyline beyond the river is the white rim of the Llano Estacado . . . . To the southwest are the flat-topped, brown, desolate ridges of the Delaware Mountains, standing several thousand feet lower than the Peak. East of them, down the slope, are the gray, rounded hills of the Gypsum Plain. Northeastward are the much higher, sharper ridges of the Guadalupe Mountains, with white limestone ledges here and there, interspersed with darker patches of forest. Erosion has left its mark over the whole sloping surface. . . . The dip of the rocks on the sloping surface appears to be gentle and unbroken. In the Delaware Mountains, one can distinguish thin, straight, bedding planes, inclined at a low angle to the east.
>
> Toward the west, the observer finds a land of entirely different aspect. He is standing on the edge of a precipice . . . and looks out, not over plains and plateaus, but over an expanse of varied, irregularly placed mountain ranges and intervening desert basins. . . . The mountains are being gashed by many short, steep water courses. . . . In the desert basins, instead of long drainage lines and a network of tributaries, one sees a host of alkaline flats and ephemeral lakes, whose white crusts gleam in the sun. . . . One infers that the land to the west may derive its form more from the raising and lowering of blocks of the earth's crust than from the wearing down of the basins between the mountains.
>
> Toward the west, the gently sloping surface of the Guadalupe and Delaware Mountains breaks off abruptly in a west-facing escarpment. . . .
>
> Projecting from the alluvial apron, between the base of the escarpment and the floor of the Salt basin, are occasional ridges, whose conspicuous ledges indicate that they are islands of bedrock, not quite engulfed by alluvium.
>
> Viewed from the peak, the Guadalupe and Delaware Mountains are thus seen to be a great asymmetrical block of the earth's crust, elongated north and south, with a gentle slope to the east and a steep escarpment to the west. Apparently the block has been uplifted

> having been sufficiently recent for the surface form to reflect rather well the underlying structure. . . . The uplift appears to have tilted the east side of the block but to have faulted off its westward side, leaving a narrow, downthrown flank. . . .

Little evidence of Precambrian history is available about the Guadalupe Mountain Region. However, the area was virtually a level plain on which Paleozoic rocks were deposited.

The area was part of a broad low-lying stable region intermittently covered by shallow seas during the most of the Paleozoic Era (until the end of the Mississipian Period). About 2,500 feet of marine depositior formed from the base of the Bliss Sandstone to the top of the Helms shale. Submarine tectonism began early in Pennsylvanian time, and the southwestern part of the area was elevated in comparison to the northeastern part, along the northwestward-trending Huapache thrust zone. Uplift was greatest in the northern areas, and probably took place beneath Pennsylvanian seas. Periodic submarine or subaerial erosion dumped reworked sediments in lower areas along the fault zone. Concurrent fault movement and local bulging of the sea bottom in the northwest produced variable thicknesses of Pennsylvanian sediments. Very early in Permian time, tectonic activity stopped and mixed continental and marine sediments deposited in low areas nearly obliterated the irregular topography caused by tectonism.

Exposed rock in the Park was deposited in association with the development of the Delaware Basin, a Permian depositional feature. During Wolfcamp time the basin, a sedimentary structure eliptical in shape and approximately 135 miles long by 75 miles wide (10,000 square miles), began to take shape. Rocks of three series of the Permian were exposed in the region, while evidence of the oldest Permian series (Wolfcampian) is not found. Along the hinge-line of the Bone Spring Monocline, the Victorio Peak Limestone was laid down.

Rocks of Leonardian and Guadalupian features in the Delaware Basin reach a thickness of 7,000 feet (Figure 12). The regional Permian sequence is relatively undisturbed (except by normal faulting) and contains one of the most complete representations of the Permian system known. Approximately 200 million years ago, differential movement

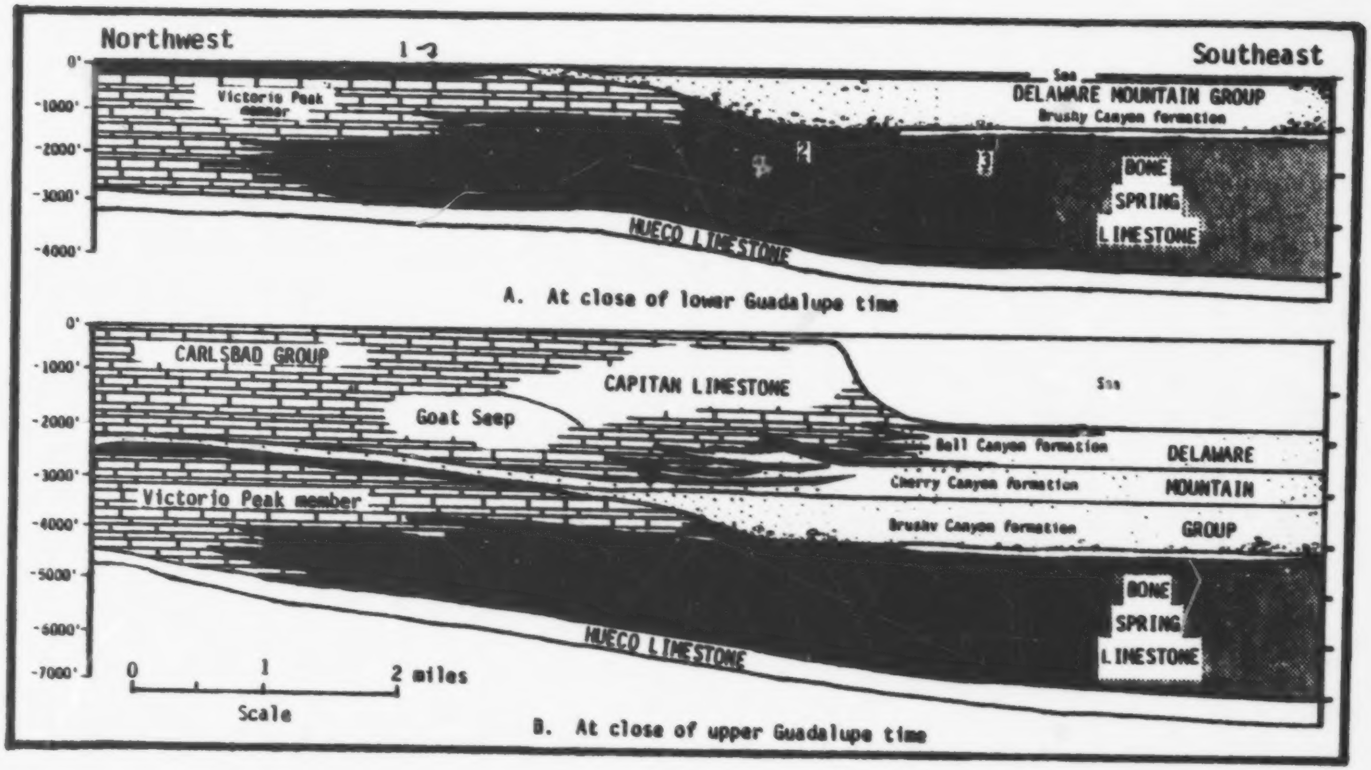


Figure 12. Profile through El Capitan showing inferred relations following deposition of Brushy Canyon formation (A) and following deposition of the Capitan reef (B). Vertical exaggeration, X 2. 1, Cutoff member, Bone Spring formation; 2, base of Cutoff member in Delaware Basin; 3, Waagenoceras shale (southern Cutoff of P.B. King, 1948), basal member, Brushy Canyon formation. (After P.B. King, U.S. Geol. Survey, Prof. Paper 215, 1948.), from Newell, et.al., 1953, p.17.

occurred along the basin margin, and the Bone Spring Arch was elevated to form a barrier between the Delaware Basin and the Northwest-shelf area. Marine deposits began to accumulate and reefs were formed.

During the early development of the Basin, when there was little difference between the threshold and Basin depths (Figure 13), winter cooling of the surface may have caused mixing due to convection currents. Also, the heavy waters (higher in salinity due to accelerated evaporation) of the shelf could have been forced into the basin by winds and replaced by lighter waters (lower in salinity). As the Basin deepened, due to growth of the barrier reef, heavy stagnant water would accumulate in the Basin until the thermocline (water "turnover") rose above the threshold and flowed as an outgoing current under the incoming water of normal salinity. Salinity was not excessive in the Basin until the lowered sea level drained the shelf, broke the threshold, and trapped the dissolved salts in a stagnating basin. Because of stagnation, enormous deposits of anhydrite (the Castile Formation) occurred and the reef was killed. Occasional influx of heavy shelf waters or thermal turnover of bottom waters provided a supply of nutrient-rich water in the upper, sunlit strata for the needs of phytoplankton responsible for the organic deposits characteristic of the Basin floor.

The rocks of the area consist mainly of Permian sedimentary sandstone and limestone, with a total exposed thickness of over 4,000 feet. The Capitan Reef complex, most significant of a number of reefs in the area, formed when subsidence of the Basin occurred at approximately the same rate as reef deposition, causing an accumulation of limestone over 2,000 feet thick (Figure 14). The Capitan Reef surrounds the Delaware Basin with a circumference of 350-400 miles. Approximately forty miles are exposed in the Guadalupe Mountains. Small outcroppings also occur in the Apache and Glass Mountains, but the majority is beneath the present land surface. While the Capitan formation measures from 1,500 to 2,000 feet in thickness (vertically), it grew predominantly horizontally and towards the Basin. In combination with the Goat Seep Reef (which grew predominantly upward), reef growth near sea level in the Guadalupe Mountains area carried the reef front more than three miles across older talus accumulations into the Delaware Basin. Figures

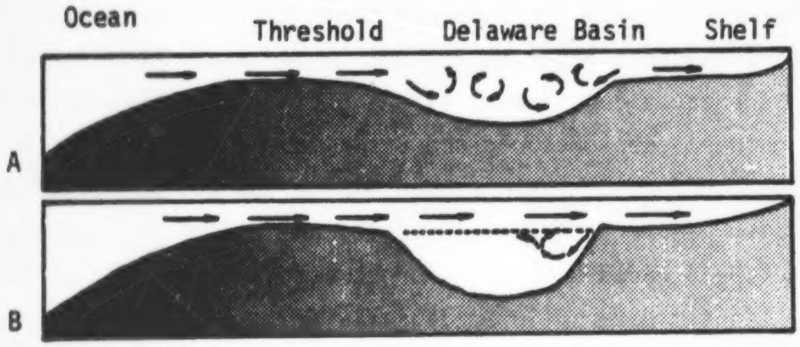


Figure 13. Inferred hydrographic relations in Delaware Basin, (A) during Wolfcampian and Leonardian times, and (B) during late Guadalupian time. During early stages surface waters sank because of winter cooling, resulting in convective overturn and partial ventilation of deep waters. During late history (B) gradual concentration of hypersaline waters below the level of the threshold and deepening of the basin favored complete stagnation below the threshold level. Ventilation of the deeper part of the basin was incomplete throughout much of Permian time; hence, prevailing negative values of Eh and low pH. Conditions were favorable for accumulation of organic material and were unfavorable for precipitation of calcareous sediments (from Newell, et. al., 1953, p. 193.).

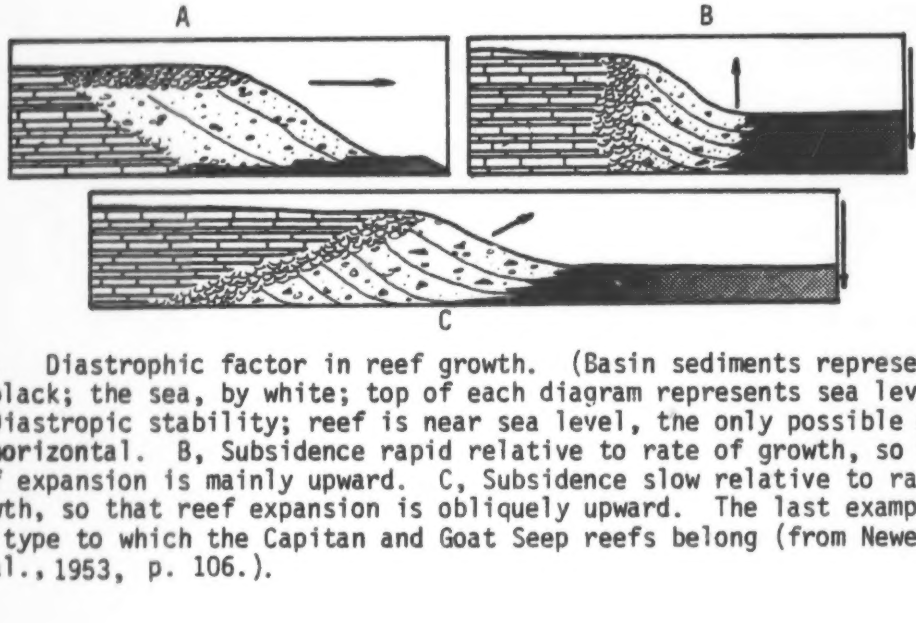


Figure 14. Diastrophic factor in reef growth. (Basin sediments represented by black; the sea, by white; top of each diagram represents sea level.) A, Diastropic stability; reef is near sea level, the only possible growth is horizontal. B, Subsidence rapid relative to rate of growth, so that reef expansion is mainly upward. C, Subsidence slow relative to rate of growth, so that reef expansion is obliquely upward. The last example is the type to which the Capitan and Goat Seep reefs belong (from Newell, et.al., 1953, p. 106.).

12 and 15 illustrate the probable developmental characteristics and depositional relationships during the Guadalupian time.

The older Permian reefs of the area are termed patch reefs, and most occurred in the Bone Spring, Brushy Canyon, and Cherry Canyon formations. These are localized structures in contrast to the more or less continuous barrier reefs (Goat Seep and Capitan).

Permian reefs are unlike the modern reef. In comparison to coral atolls, the position of sea and lagoon are reversed. The reef is located around the rim of the sea, which overflows the basin and covers shallow pans behind the reef. Thus the term barrier reef, because of their profound effect on Permian circulation and sedimentation.

To say the least, development of the reef and basin sedimentation are dependent on the flora and faunal populations of the waters that covered the entire area at various times. Included here are the common groups having been identified as Permian inhabitants of the Delaware Basin:

1. Fusulines
2. Sponges
3. Corals
4. Echinoderms
5. Brachiopods
6. Bryozoans
7. Gastropods
8. Pelecypods
9. Ammonoids
10. Natuiloids
11. Scapopods
12. Ostracops
13. Trilobites

Broad epeirogenic uplift at the end of Permian time left the entire region dry. Triassic or Jurrassic rocks are not found in the region. There may or may not have been deposition during late Triassic flooding, but the evidence has been stripped off if they were ever present. Once again in the Early Cretaceous, shallow seas again covered the area, indicated by fossiliferous limestones, coarse sandstones, and conglomerates currently present.

The region was probably elevated again slightly in the early Tertiary, and subjected to mild tectonism. This tectonism produced the Walnut Canyon syncline, Guadalupe Ridge anticline, and related features. It was during these times that the ancestral northeast-flowing drainage system was established.

During the Pliocene epoch, the continental Ogalla Formation was deposited to the east, but it is not evident that this formation ever covered the project area.

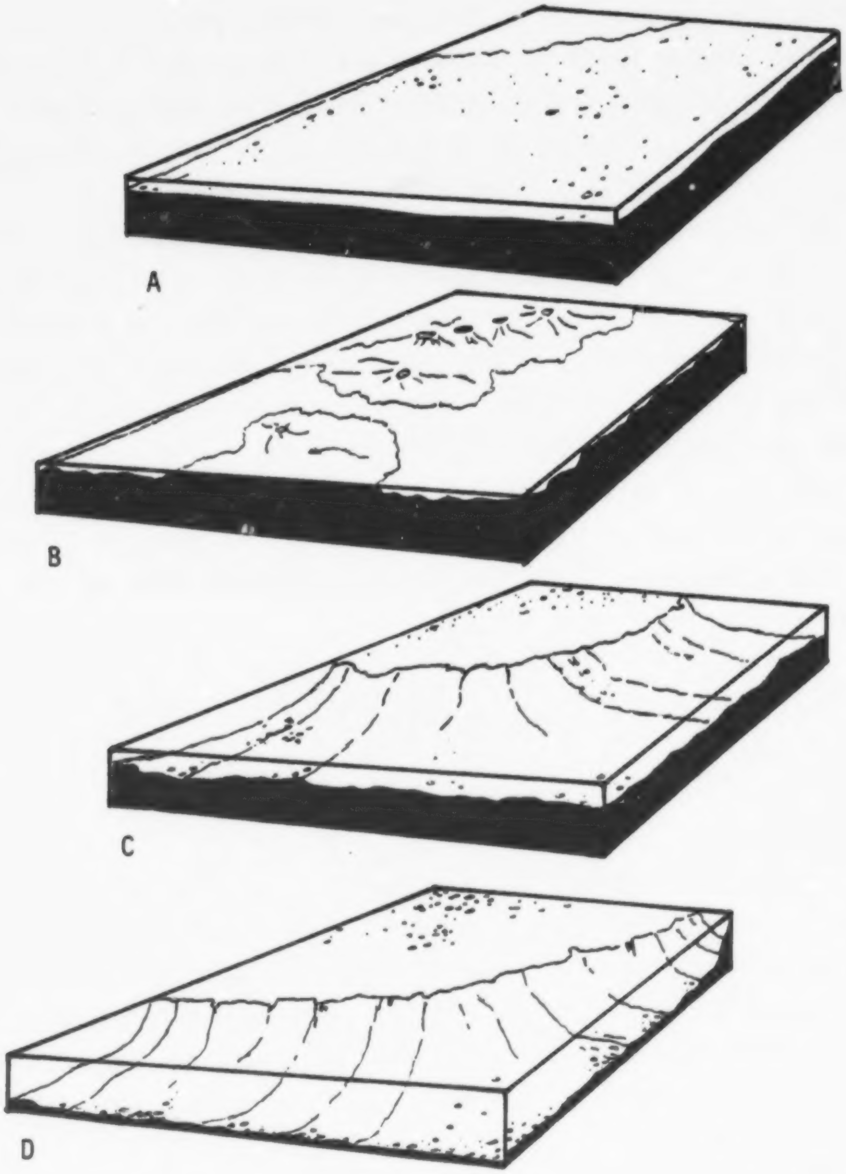


Figure 15. Evolution of reef, shelf, and basin environments during Guadalupian time. A, Early Brushy Canyon time. B, Getaway time, growth of small patch reefs. C, Late Cherry Canyon time, Goat Seep barrier reef. D, Early Bell Canyon Time, Capitan barrier reef (from Newell, et.al., 1953, p. 104.).

A majority of the uplift and faulting probably occurred late in the Pliocene and early in the Pleistocene. The uplift caused a strata rise from a low position at the east and west edges to a high position near the center of the study area. The crest extends north and south from Guadalupe Peak along the escarpment at the west edge of the mountains. The simple arch is complicated by a fault belt about 10 miles wide, parallel to the crest and western flank of the uplift (Border Fault zone). The faults of the zone drop the strata westward from 2,000 to 4,000 feet. Although most major drops take place at one fault, no single fault is continuous along the entire course of the zone.

Within the Border fault zone, the Guadalupe Peak horst (about 9 miles long and 2 to 3 miles wide) is noticeably free of faults. The highest part of the uplift is the half-dome forming Guadalupe Peak.

The present drainage systems and landforms have formed since the mountain uplift and are still being modified. Rates of erosion, deposition, and carbonate precipitation fluctuate considerably with climatic cycles.

## INTENSIVE STUDY AREA

Each of the intensive study watersheds was characterized as to geologic parent materials. Tables 8 through 13 present summaries of the geologic composition for each watershed. Figures 16 through 20 are surficial geology maps of the watersheds upon which the composition data were determined. Rock types are utilized in this mapping rather than the more traditional geologic formations, the rock types being of perhaps greater importance to land-use planning activities as well as predictions of hydrologic responses (Goolsby and Reeves, 1975).

The Carlsbad Limestone and the Pinery Member of the Bell Canyon Formation are combined and mapped as thin bedded limestone and/or dolomite (Tl). Coarse Quaternary stream and slope wash sediments mapped as Qc contain cobbles, gravels and sands which are usually cemented by calcium carbonate near the surface but tend to be non-indurated at depths greater than five or ten feet. Finer grained Quaternary deposits mapped as Qc-fl are composed of some fluvial deposits (sand, gravels, and cobbles) and lacustrine sediments (silt, clay and evaporites), with eolian, silt-sized debris blown in from the salt lake

## TABLE 8. SURFICIAL GEOLOGY COMPOSITION WATERSHED 1

| Surface Rock Type | Percent Area | Acres | Area Sq. Miles |
|---|---|---|---|
| Massive or Thick bedded limestone or dolomite (Ml) | 5 | 160 | 0.25 |
| Thin bedded limestone and/or dolomite (Tl) | 86 | 2712 | 4.24 |
| Sandstone (SS) | 6 | 192 | 0.30 |
| Generally coarse, often partially consolidated (Qc) | 3 | 96 | 0.15 |
|  | 100 | 3160 | 4.94* |

* Includes only area within National Park boundary

## TABLE 9. SURFICIAL GEOLOGY COMPOSITION WATERSHED 10A6

| Surface Rock Type | Percent Area | Acres | Area Sq. Miles |
|---|---|---|---|
| Massive or thick bedded limestone or dolomite (Ml) | 37 | 922 | 1.44 |
| Thin bedded limestone and/or dolomite (Tl) | 15 | 371 | 0.58 |
| Sandstone (SS) | 12 | 301 | 0.47 |
| Coarse to fine material, non-consolidated (Qc-fl) | 29 | 723 | 1.13 |
| Shale (SH) | 7 | 173 | 0.27 |
|  | 100 | 2490 | 3.89 |

## TABLE 10. SURFICIAL GEOLOGY COMPOSITION WATERSHED 8B

| Surface Rock Type | Percent Area | Acres | Area Sq. Miles |
|---|---|---|---|
| Thin bedded limestone and/or dolomite (Tl) | 6 | 6 | 0.01 |
| Generally coarse, often partially consolidated (Qc) | 94 | 90 | 0.14 |
|  | 100 | 96 | 0.15 |

## TABLE 11. SURFICIAL GEOLOGY COMPOSITION WATERSHED 8D

| Surface Rock Type | Percent Area | Acres | Area Sq. Miles |
|---|---|---|---|
| Generally coarse, often partially consolidated (Qc) | 100 | 346 | 0.54 |
|  | 100 | 346 | 0.54 |

## TABLE 12. SURFICIAL GEOLOGY COMPOSITION WATERSHED 7

| Surface Rock Type | Percent Area | Acres | Area Sq. Miles |
|---|---|---|---|
| Massive or Thick bedded limestone or dolomite (Ml) | 40 | 429 | 0.67 |
| Thin bedded limestone and/or dolomite (Tl) | 29 | 314 | 0.49 |
| Sandstone (SS) | 14 | 147 | 0.23 |
| Generally coarse, often partially consolidated (Qc) | 16 | 173 | 0.27 |
| Coarse to fine material non-consolidated (Qc-fl) | 1 | 13 | 0.02 |
| | 100 | 1076 | 1.68 |

## TABLE 13. SURFICIAL GEOLOGY COMPOSITION WATERSHED 6

| Surface Rock Type | Percent Area | Acres | Area Sq. Miles |
|---|---|---|---|
| Massive cr Thick bedded limestone or dolomite (Ml) | 60 | 8269 | 12.92 |
| Thin bedded limestone and/or dolomite (Tl) | 36 | 4960 | 7.75 |
| Sandstone (SS) | 3 | 410 | 0.64 |
| Generally coarse, often partially consolidated (Qc) | T | 6 | -- |
| Coarse to fine material, non-consolidated (Qc-fl) | 1 | 141 | 0.22 |
| | 100 | 13786 | 21.53* |

* Includes only area within National Park boundary

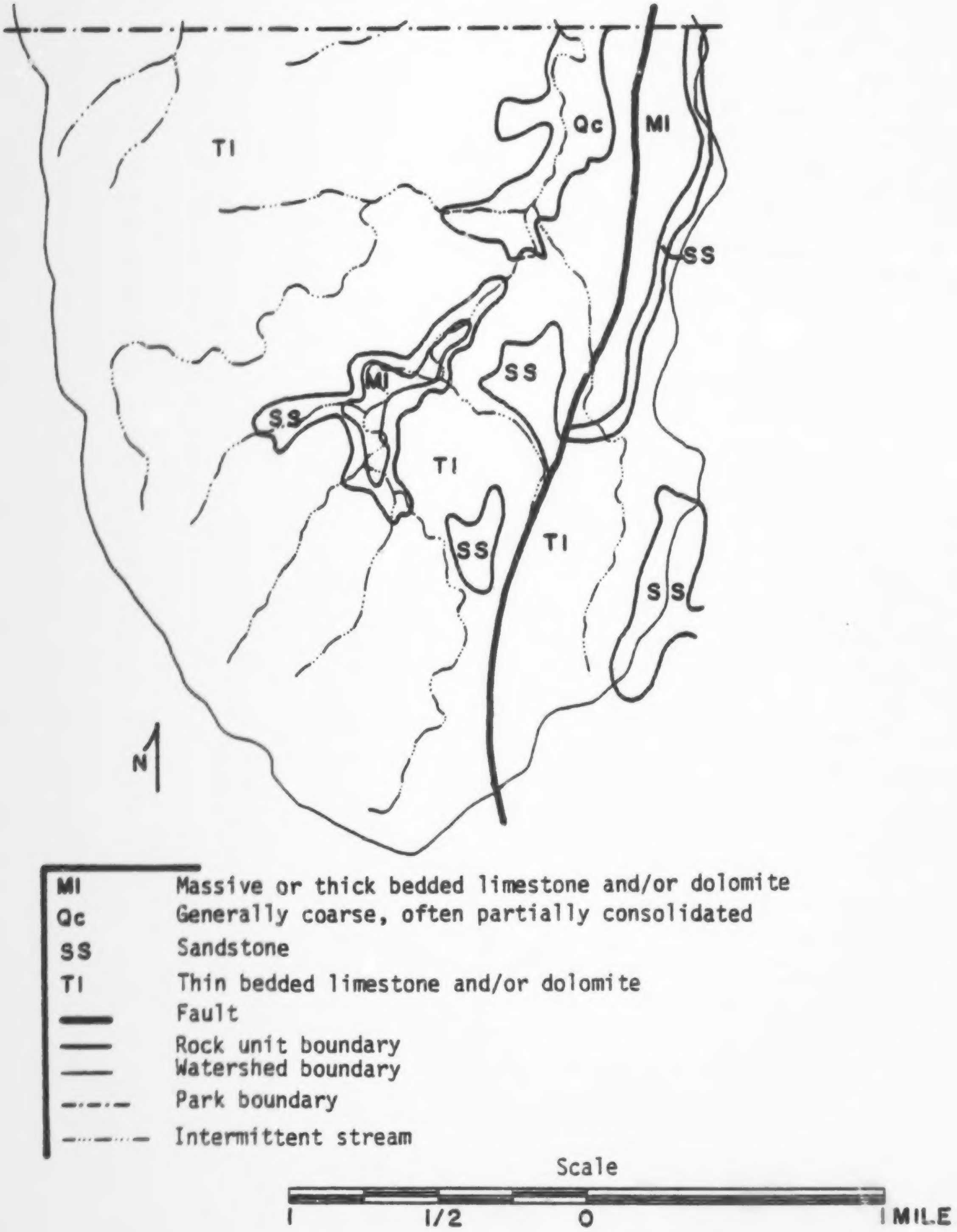
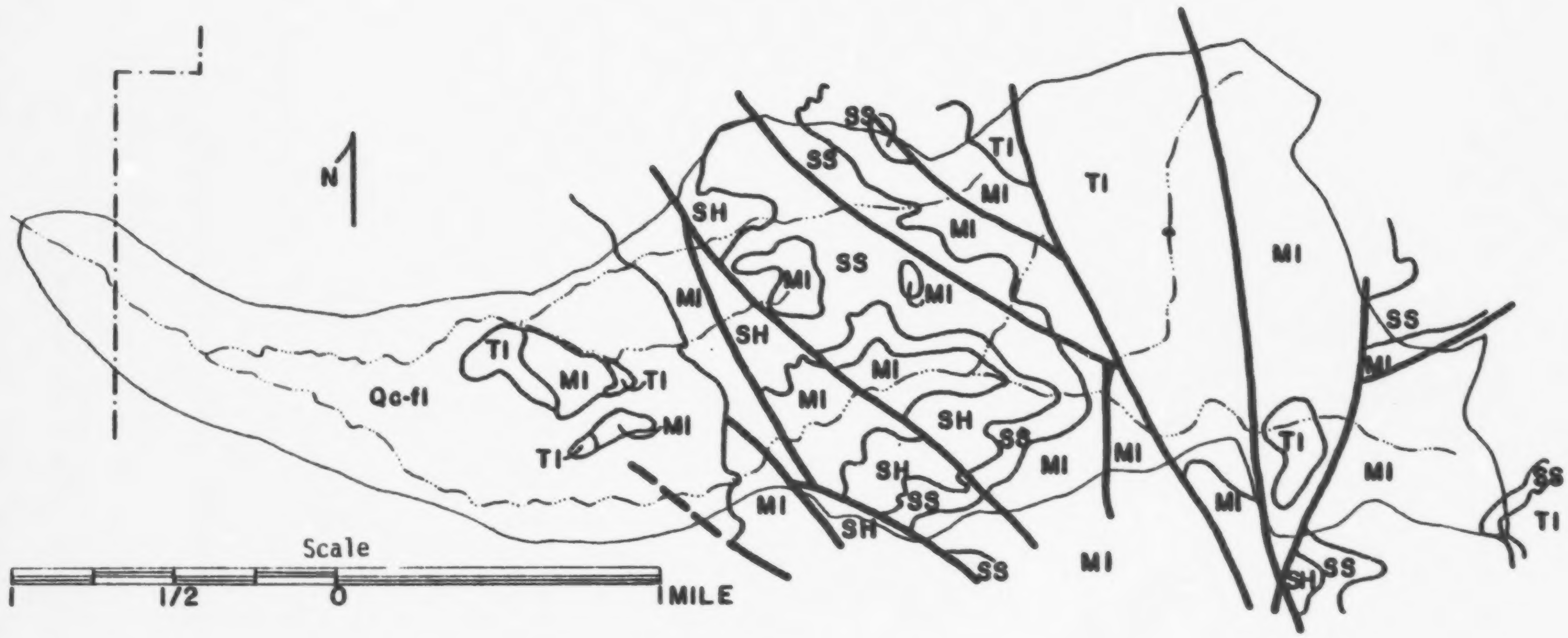

Tl
Qc
Ml
SS
SS
Ml
Ss
Tl
SS
Tl
S S
N
Ml Massive or thick bedded limestone and/or dolomite
Qc Generally coarse, often partially consolidated
SS Sandstone
Tl Thin bedded limestone and/or dolomite
Fault
Rock unit boundary
Watershed boundary
Park boundary
Intermittent stream
Scale
1
1/2
0
1 MILE

Figure 16. Surface Rock Material Watershed 1.



| | |
|---|---|
| MI | Massive or thick bedded limestone and/or dolomite |
| Qc-fl | Coarse to fine material, non-consolidated |
| SH | Shale |
| SS | Sandstone |
| TI | Thin bedded limestone and/or dolomite |
| ━━ | Fault |
| ▬ ▬ ▬ | Inferred fault |
| ─── | Rock unit boundary |
| ─── | Watershed boundary |
| —·—·— | Park boundary |
| —··—··— | Intermittent stream |

Figure 17. Surface Rock Material Watershed 10A6.

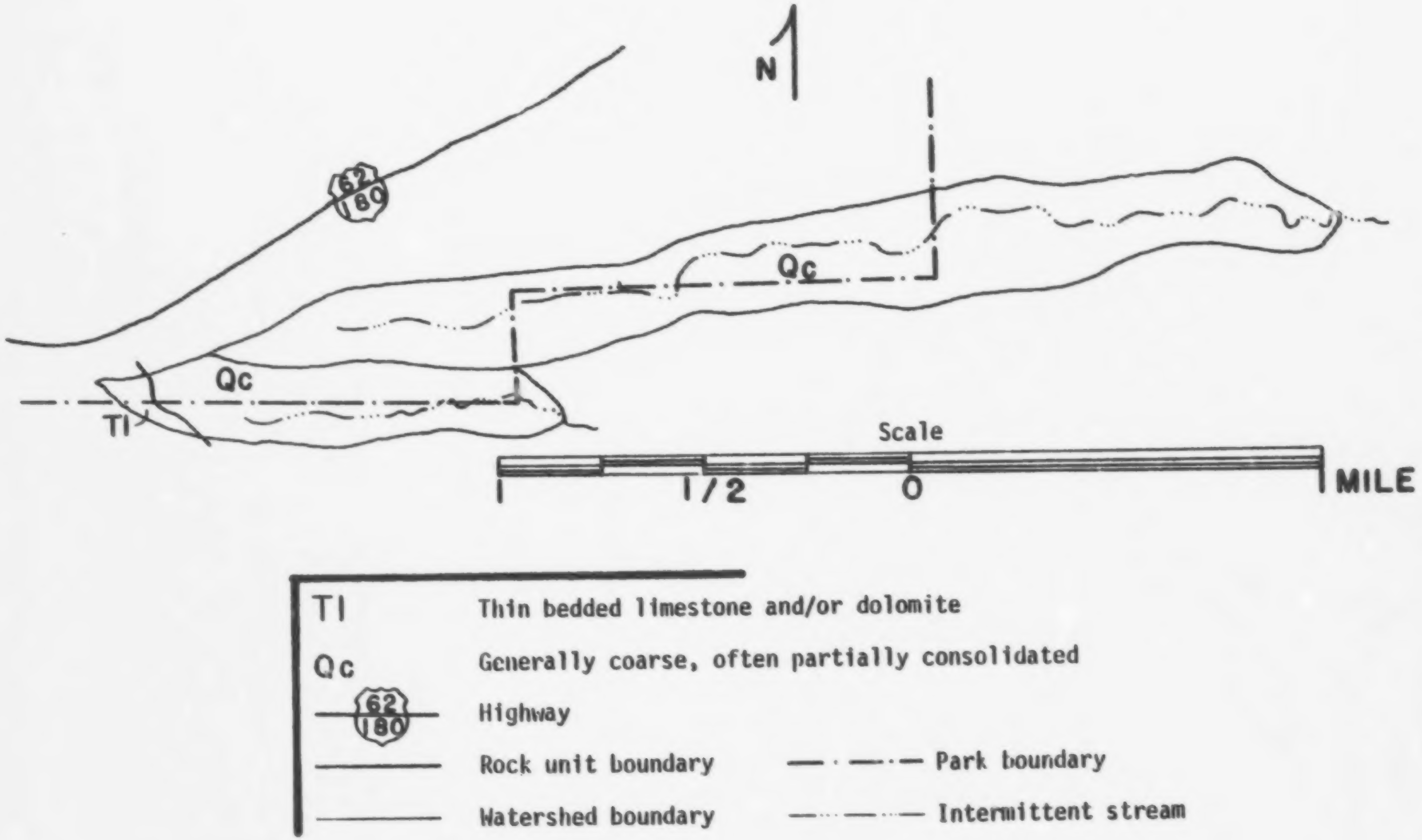


Figure 18. Surface Rock Material Watershed 8B-8D.

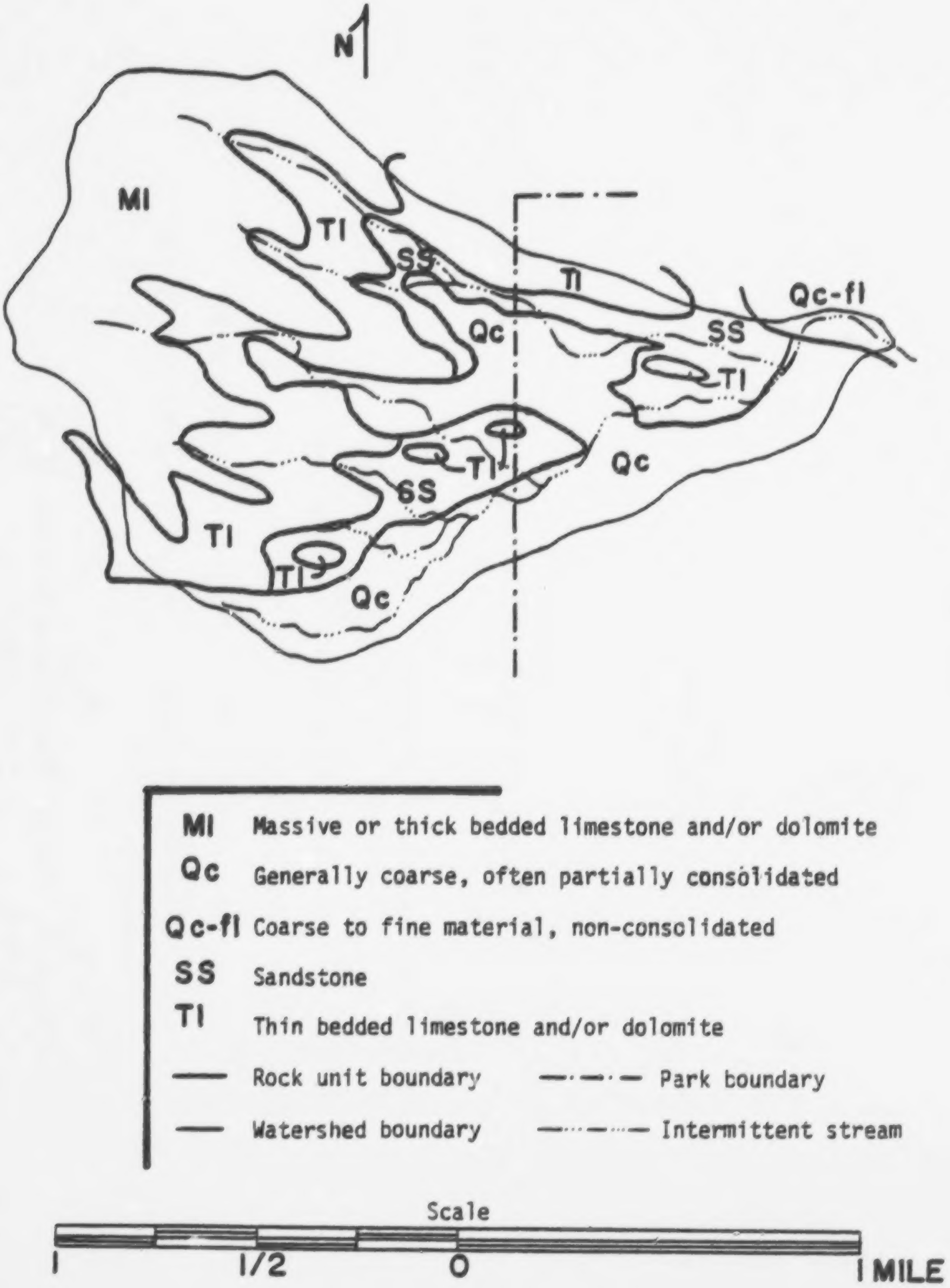

N
Ml
Tl
SS
Tl
Qc
SS
Qc-fl
Tl
Qc
Tl
SS
Tl
Tl
Qc
Ml Massive or thick bedded limestone and/or dolomite
Qc Generally coarse, often partially consolidated
Qc-fl Coarse to fine material, non-consolidated
SS Sandstone
Tl Thin bedded limestone and/or dolomite
Rock unit boundary
Park boundary
Watershed boundary
Intermittent stream
Scale
1
1/2
0
1 MILE

Figure 19. Surface Rock Material Watershed 7.

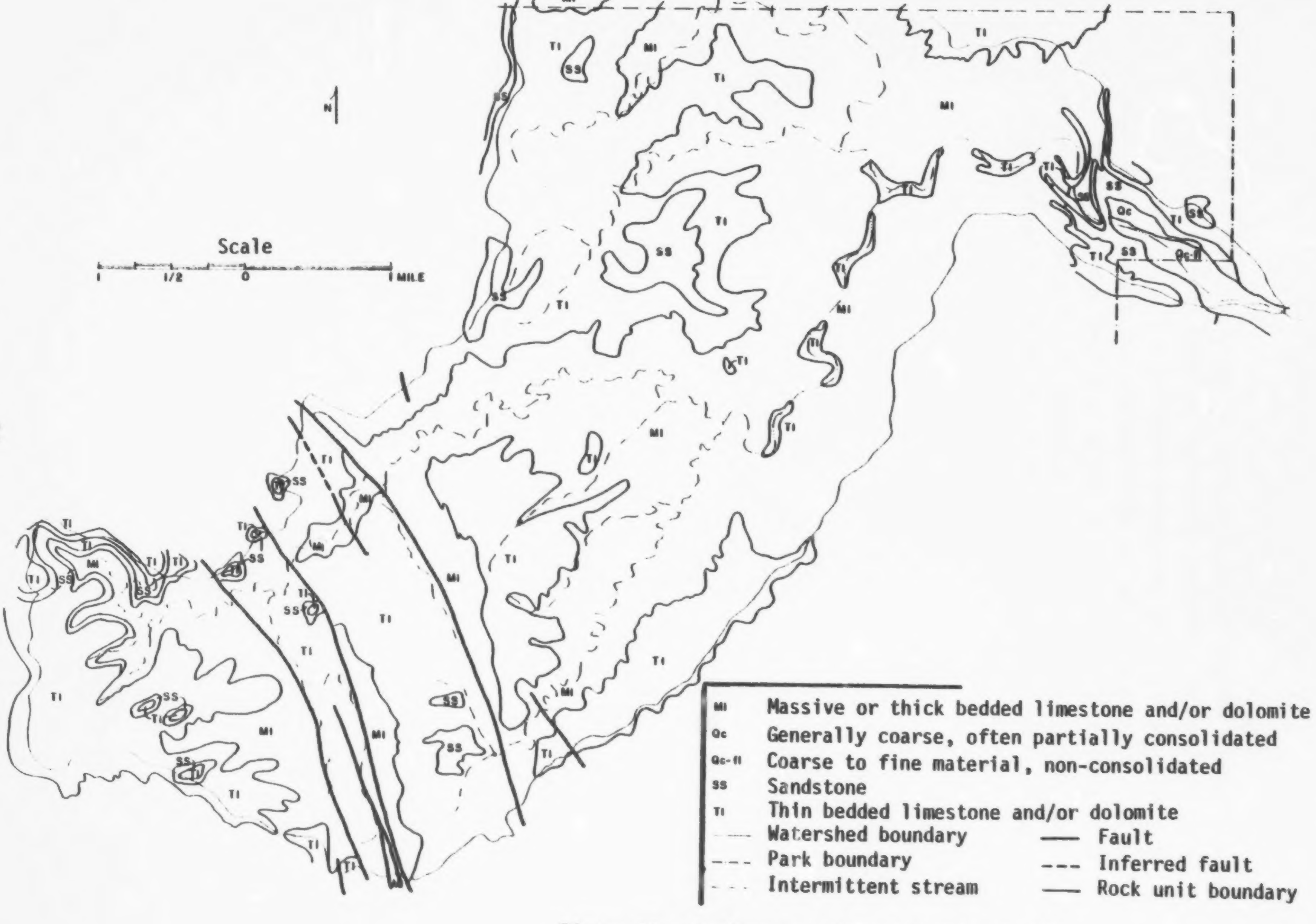

Scale
1
1/2
0
1 MILE
N
Mi
Ti
SS
Qc
Qc-II
Mi Massive or thick bedded limestone and/or dolomite
Qc Generally coarse, often partially consolidated
Qc-II Coarse to fine material, non-consolidated
SS Sandstone
Ti Thin bedded limestone and/or dolomite
Watershed boundary
Park boundary
Intermittent stream
Fault
Inferred fault
Rock unit boundary

Figure 20. Surface Rock Material Watershed 6.

basin on the western side of the park. These materials are essentially unconsolidated and therefore susceptible to rapid erosion. Other thinly-bedded units included shales mapped as SH and sandstones mapped as SS. Massive or thickly bedded limestones and dolomites were mapped as Ml and consisted primarily of Capitan Limestone which is a fossiliferous, massive unit which may be arenaceous and/or extensively dolomitized locally (Goolsby and Reeves, 1975; Railsback and Reeves, 1976).

# CLIMATE V CLIMATOLOGY

## INTRODUCTION

Climatic conditions within Guadalupe Mountains National Park can be most accurately characterized by two words--extreme and variable. Although encompassing only 77,500 acres, the park contains the major topographic discontinuity in this portion of West Texas, which is largely responsible for the uniqueness of this site. Regionally the area can be classified as having a continental semi-arid environment with 70 percent or more of the average annual precipitation occurring during a 180-210 day growing season.

Because of the extreme elevational gradients associated with the escarpment and the sheltered nature of locations interior to the escarpment, useful climatic characterizations must be particularly site specific and extrapolation of data must be carefully linked to locational parameters. The objectives of this research program necessitated installation of meteorological monitoring stations which would reflect locational variations of data within the park; provide a basis for data extrapolation from long-term stations outside the park; and record events of significance to the hydrologic response of the intensive study watersheds.

Five locations were selected for the installation of recording instruments within the park (Figure 21). Six stations with varying terms of record were selected from adjacent areas outside the park for investigations on their potential for extrapolation of historical

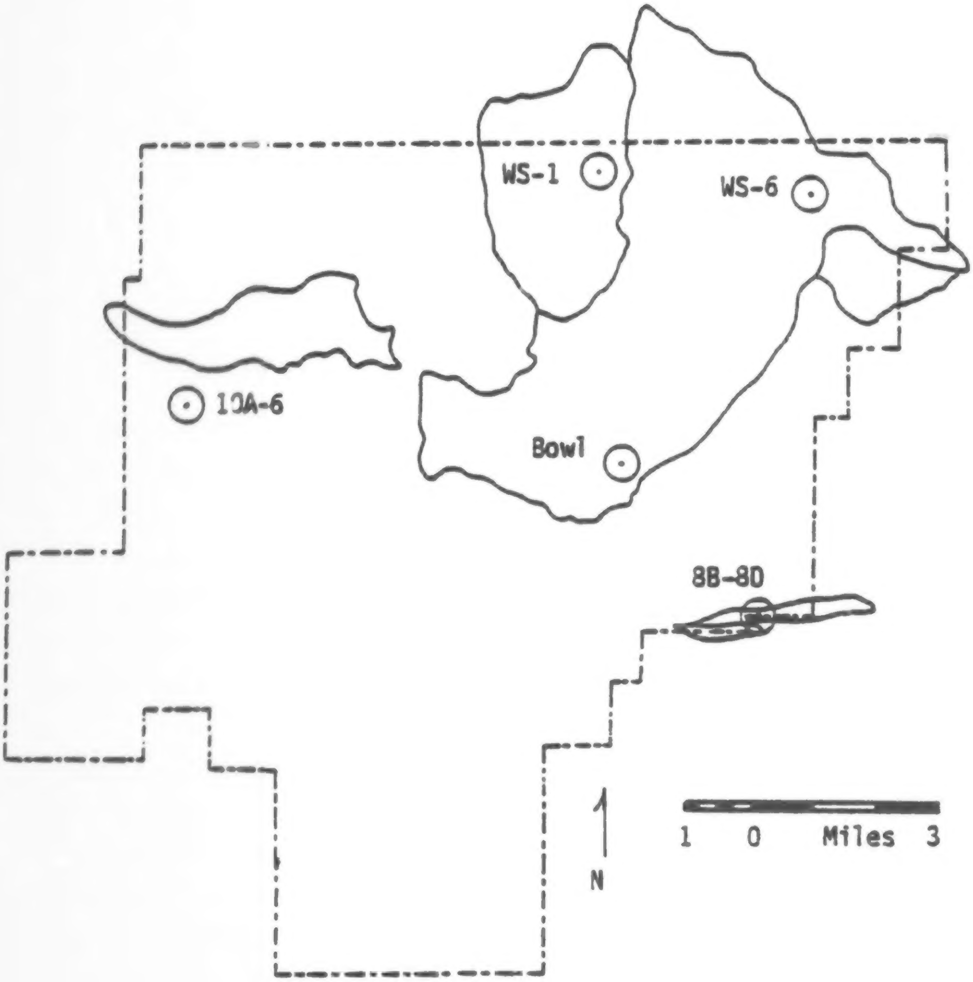


Figure 21. Weather Station Locations.

records for the park (Figure 22). Following a description of the types of instruments used in the stations, results from each location will be reported and analyzed. Finally a discussion of the relationships of the various stations will be presented. Daily summaries of all data on a station-by-station basis have been filed at the visitor information center in the park for future use by other investigators. All data has also been converted to computer records at Texas Tech University and is available for subsequent analysis and investigation.

## INSTRUMENTATION

Precipitation events were recorded at locations WS-6, 8B-8D and 10A6 with Weathermeasure P501-1 tipping bucket rain gages, and Weathermeasure P521 event recorders with 7 or 31 day drum rotations.* Units were enclosed in a protective metal cabinet to preclude tampering in unattended areas (Figure 23). Locations WS-1 and Bowl were equipped with Weathermeasure P511P remote recording, propane heated snow gages. This instrument operates with similar components to the previous stations except that a fiber glass enclosure and insulation permits cold weather operation. The snow gages were installed with Weathermeasure P565 Alter Windshields to improve accuracy of snow accumulation measurements (Figure 24).

Temperature and humidity data were recorded at locations WS-1, WS-6 and 8B-8D using Weathermeasure H311 hygrothermographs with 7 or 31 day drum rotation. These instruments were located in standard weather bureau instrument shelters (Figure 25).

Solar radiation data was recorded at WS-6 using a Weathermeasure R401 mechanical pyranograph. The metal cabinet which housed the precipitation instrument was adapted to also house and protect this instrument (Figure 26).

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*The use of manufacturers' names is intended solely for specific identification of equipment utilized and does not imply any form of endorsement by Texas Tech University or other agencies involved in this research.

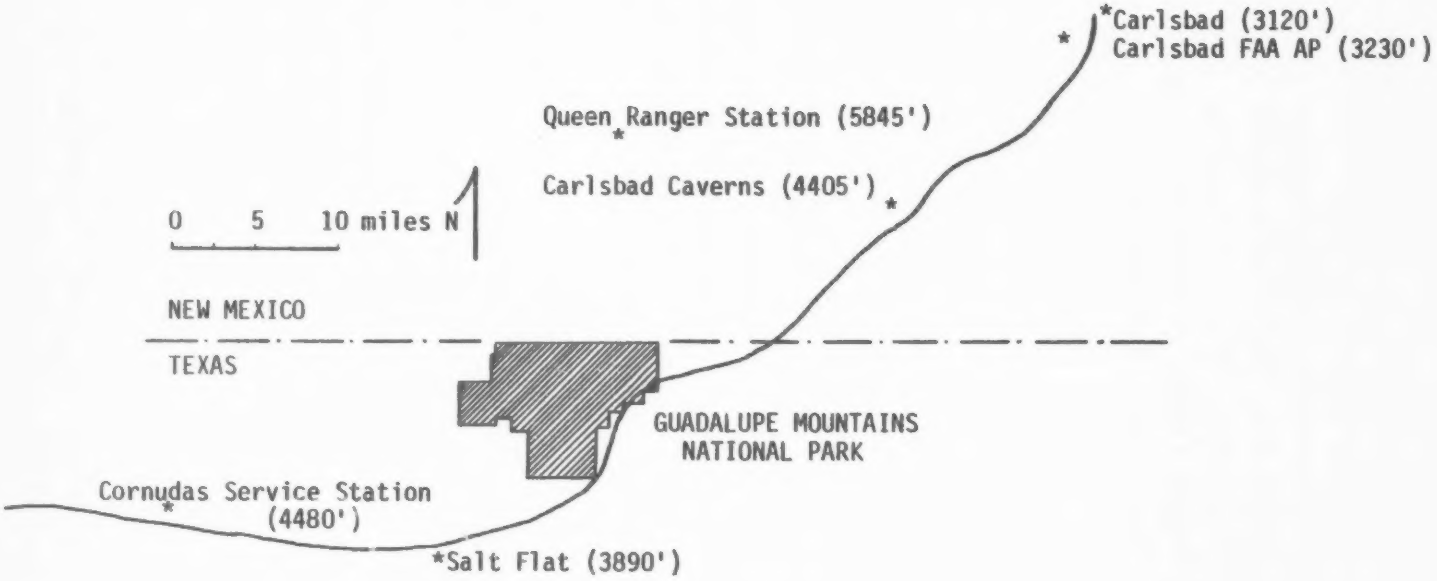

Figure 22. NOAA Precipitation and Temperature Recording Station Locations.

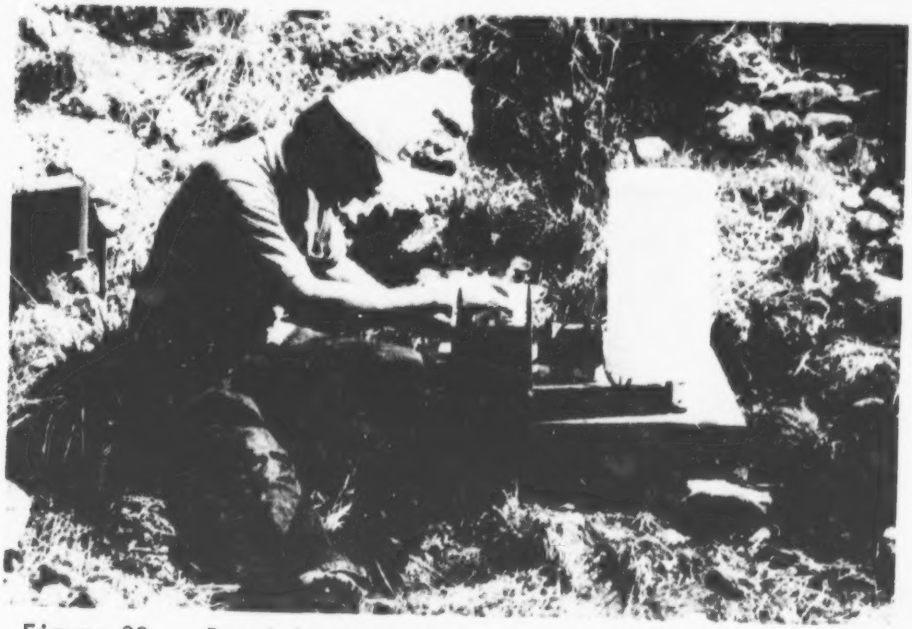

Figure 23. Precipitation gage and instrument enclosure. Location WS-6.

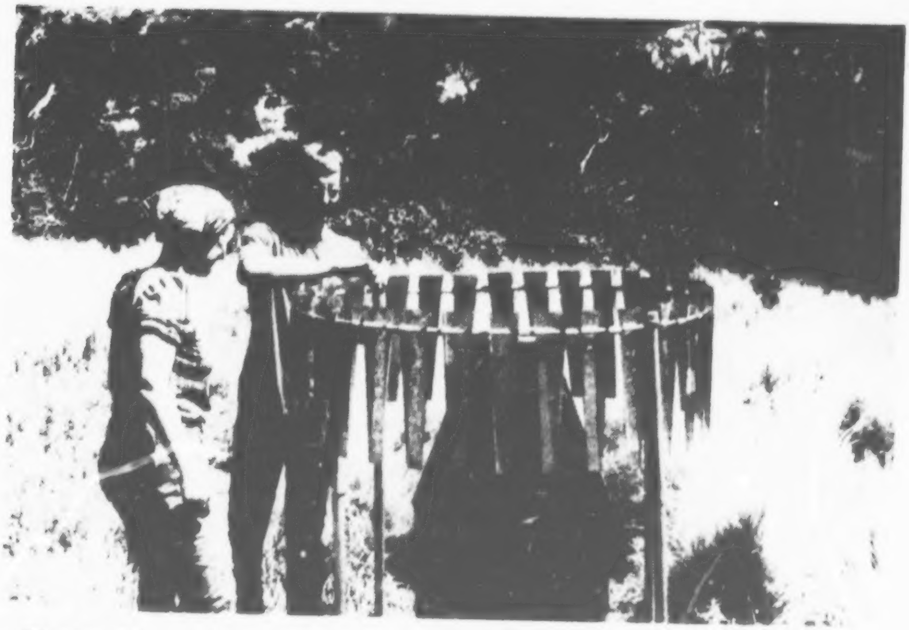

Figure 24. Propane heated snow gage with Alter windshield. Location WS-1.

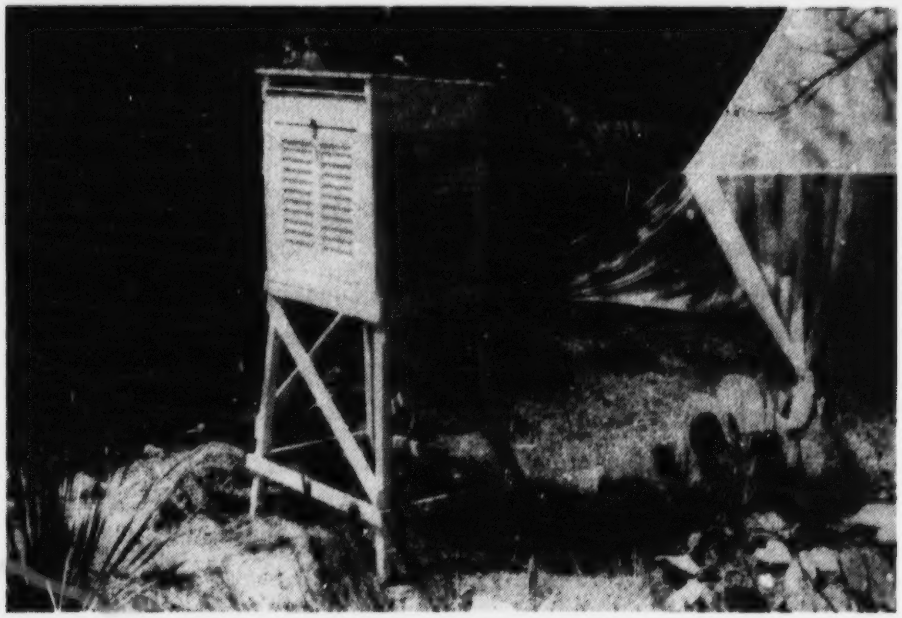

Figure 25. Hygrothermograph instrument shelter. Location WS-6.

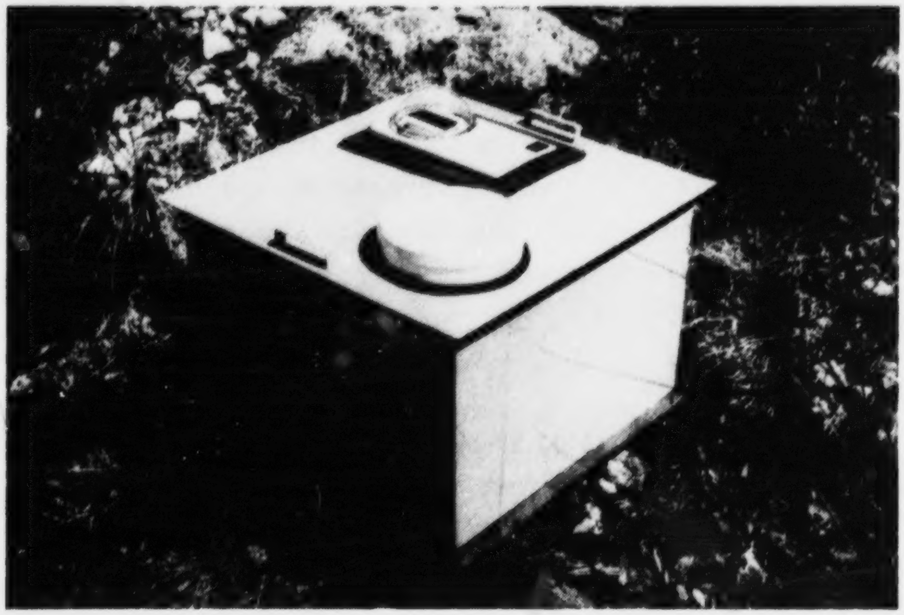

Figure 26. Precipitation gage and mechanical pyranograph. Location WS-6.

## RESULTS

### STATION WS-1

Instrumentation at station WS-1 was completed in July 1977. The station is located at 6280 feet elevation, 31°59'34" N latitude, 104°49'59" W longitude near the Dog Canyon Ranger Station. The site is on an alluvial fill west of the Dog Canyon channel. There is less than 1% slope in the immediate vicinity of the site. Surrounding vegetation is dominantly open grassland with a wooded area to the south and east.

Monthly precipitation totals are shown graphically in Figure 27. During the study period July 1977 - August 1979, 211 precipitation events were recorded. Table 14 presents a summary of these events by intensity intervals.

Monthly average temperature and relative humidity are presented in Figures 28 and 29. Temperature extremes recorded at this site during the study period ranged from a low of -5F at 2100 hours on 8 December 1978 to a high of 97F at 1700 hours on 25 June 1978. Relative humidity reached 100% on numerous occasions and a low of 4% was recorded on 0400-0430 hours on 17 March 1978.

In relation to other recording stations within the park station WS-1 ranked fourth in total precipitation and was the coolest station with respect to average monthly temperature. With regard to average monthly humidity, WS-1 was between the other two recording stations during the study period.

### STATION 8B-8D

Instrumentation at station 8B-8D was completed in late June 1977. The station is located at 5385 feet elevation, 31°53'38" N latitude, 104°47'38" W longitude approximately one-half mile southeast of the visitor information center and administrative office location. The site is on a small ridge in the partially dissected bajada extending eastward from the park boundary along the mountain front. Surrounding vegetation is dominantly an open mountain shrub/grassland community. The slope is approximately 5% with a south-southeast aspect.

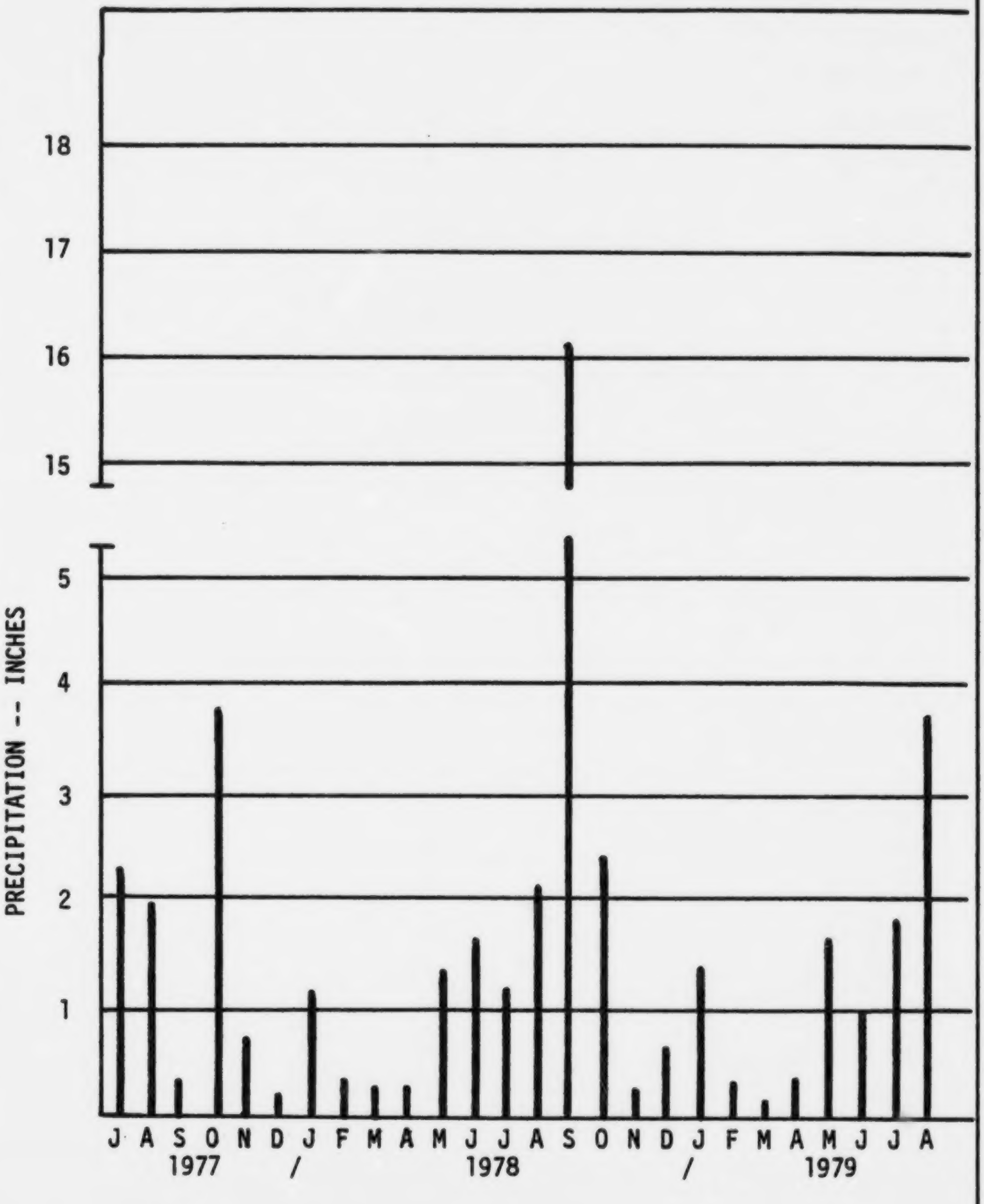

Figure 27. Precipitation -- Station WS-1.

TABLE 14. PRECIPITATION INTENSITY SUMMARY STATION WS-1

| Intensity Interval (inches/hour) | Number of Events | Frequency Percent |
|---|---|---|
| 0.00-0.25 | 145 | 68.8 |
| 0.25-0.50 | 45 | 21.3 |
| 0.50-0.75 | 10 | 4.7 |
| 0.75-1.00 | 6 | 2.8 |
| 1.00-1.50 | 4 | 1.9 |
| 1.50-2.00 | 1 | 0.5 |
| 2.00-3.00 | 0 | 0.0 |
| 3.00-4.00 | 0 | 0.0 |
| Total | 211 | 100.0 |

TABLE 15. PRECIPITATION INTENSITY SUMMARY STATION 8B-8D

| Intensity Interval (inches/hour) | Number of Events | Frequency Percent |
|---|---|---|
| 0.00-0.25 | 152 | 69.1 |
| 0.25-0.50 | 32 | 14.5 |
| 0.50-0.75 | 20 | 9.1 |
| 0.75-1.00 | 10 | 4.5 |
| 1.00-1.50 | 5 | 2.3 |
| 1.50-2.00 | 1 | 0.5 |
| 2.00-3.00 | 0 | 0.0 |
| 3.00-4.00 | 0 | 0.0 |
| Total | 220 | 100.0 |

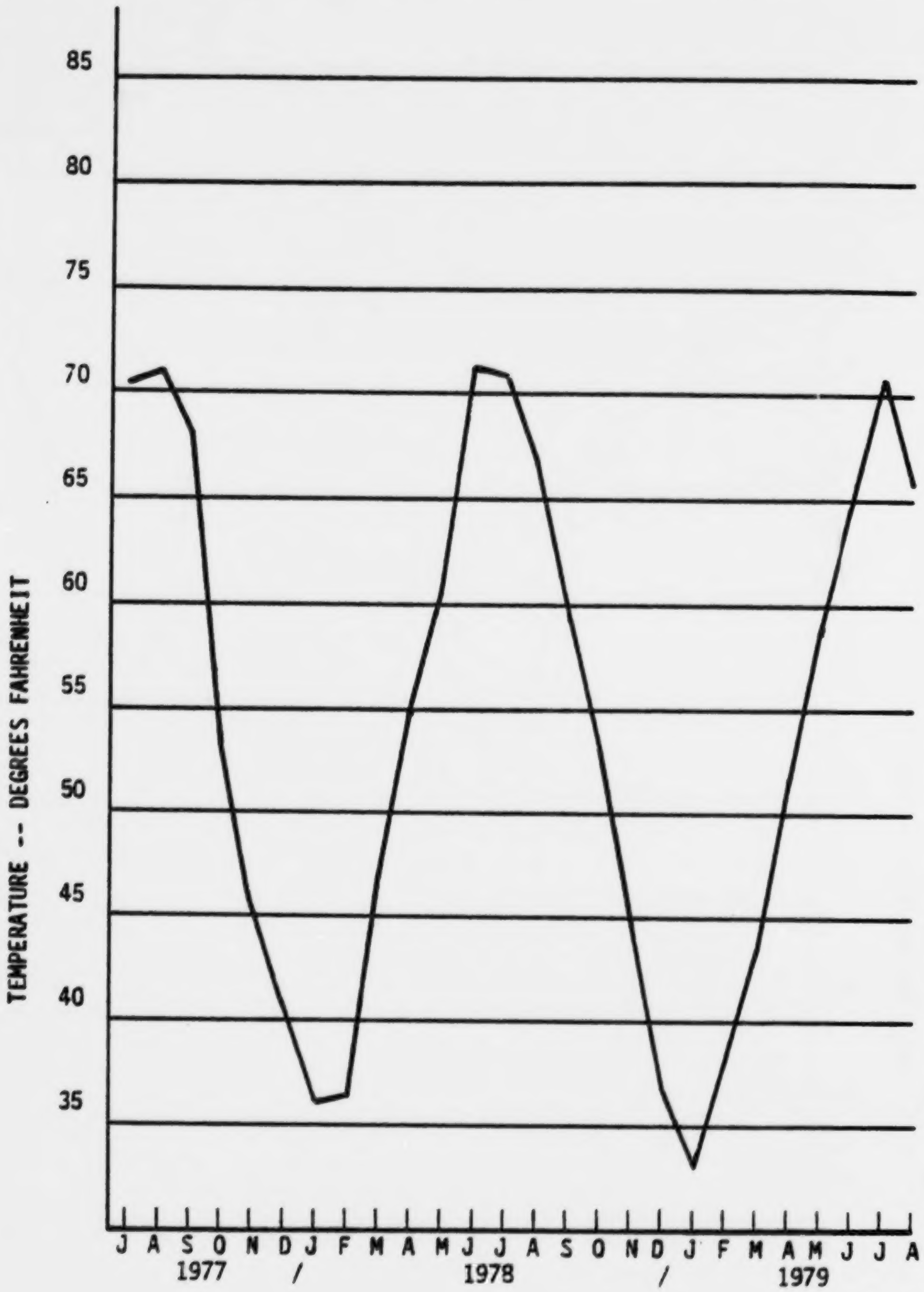

Figure 28. Temperature -- Station WS-T.

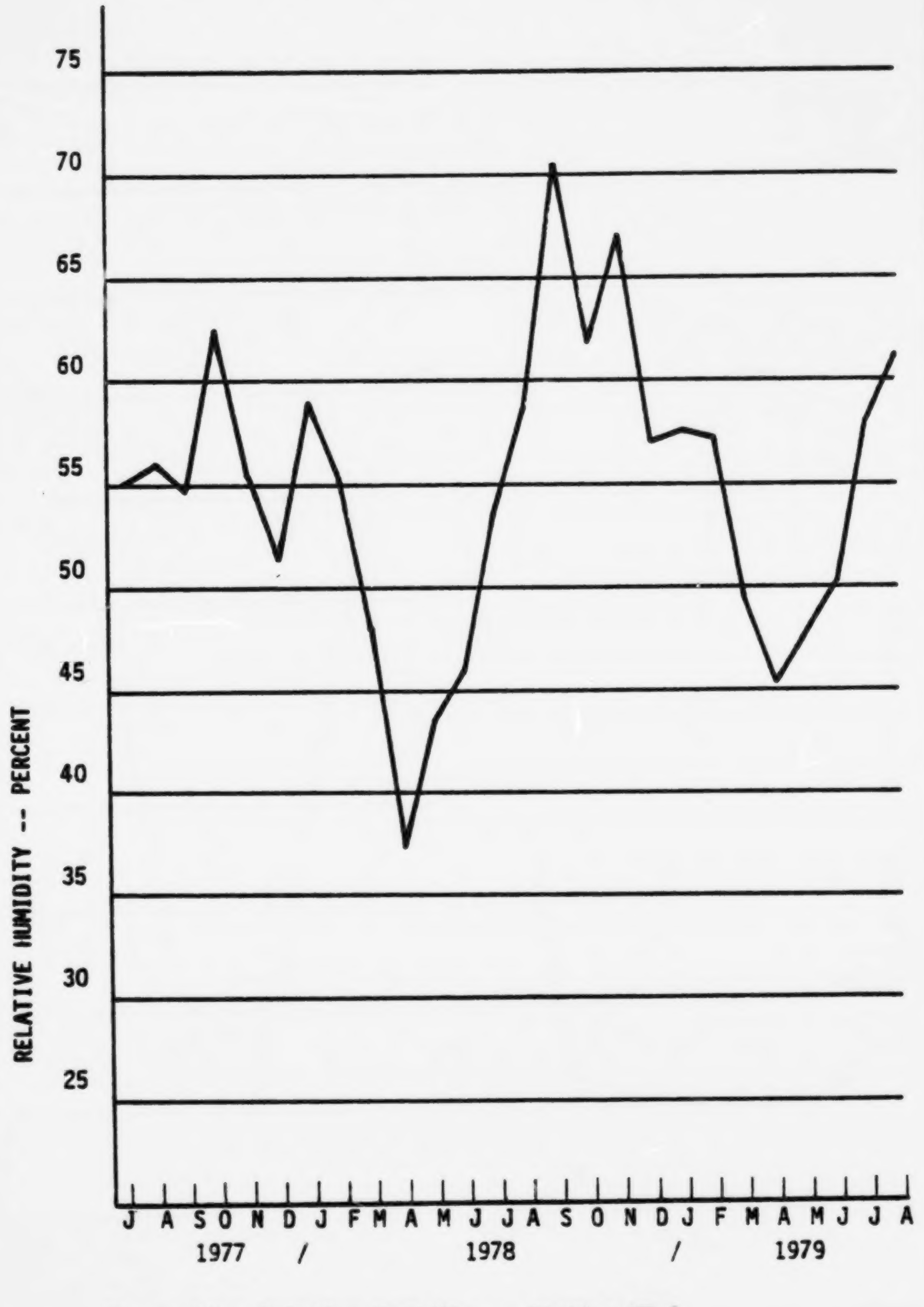

Figure 29. Relative Humidity -- Station WS-1.

Monthly precipitation totals are shown graphically in Figure 30. During the study period July 1977 through August 1979, 220 precipitation events were recorded. Table 15 presents a summary of these events by intensity intervals.

Monthly average temperature and relative humidity are presented in Figures 31 and 32. Temperature extremes recorded at this site during the study period ranged from a low of -6F at 0600 hours on 2 January 1979 to a high of 100F at 1645 hours on 25 June 1978 and at 1330 hours on 11 July 1979. Relative humidity reached 100% on numerous occasions and a low of 2% was recorded at 1000 hours on 7 December 1977.

In relation to other recording stations within the park, station 8B-8D ranked third in total precipitation and was slightly warmer and drier with respect to temperature and humidity during the study period.

## STATION WS-6

Instrumentation at station WS-6 was completed in mid August 1977. The station is located at 5235 feet elevation, 31°59'02" N latitude, 104°46'46" W longitude, near the Pratt Lodge in McKittrick Canyon. The site is located at the base of the north canyon wall where it meets the highest alluvial terrace of North McKittrick Canyon. The precipitation and solar radiation instruments are located 50 feet up the slope to position them out from under the tree canopy which occurs on the terrace. The hygrothermograph is situated on the terrace which has less than 1% slope in the immediate vicinity of the station. The slope site has a south aspect with greater than 50% slope. The topographic discontinuity coincides with a vegetative boundary between mountain shrub on the slope and deciduous forest on the terrace.

Monthly precipitation totals are shown graphically in Figure 33. During the study period June 1977 through August 1979, 320 precipitation events were recorded. Table 16 presents a summary of these events by intensity intervals.

Monthly average temperature and relative humidity are presented in Figures 34 and 35. Temperature extremes recorded at this site during the study period ranged from a low of -4F at 0100-0115 hours on 9 December 1978 and at 0600-0645 hours on 2 January 1979 to a high of 100F at 1400 hours on 13 July 1979. Relative humidity reached 100% on

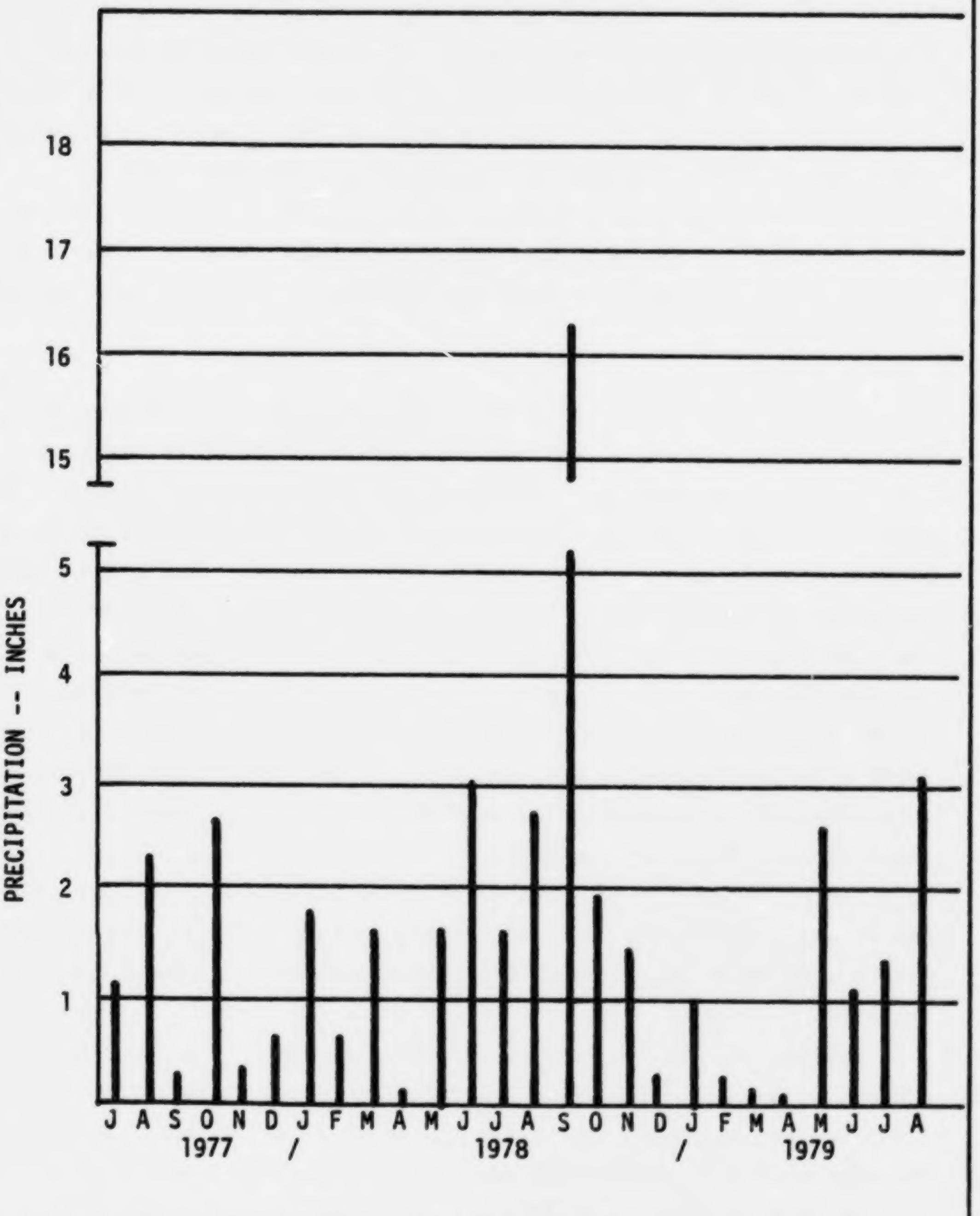

Figure 30. Precipitation -- Station 8B-8D.

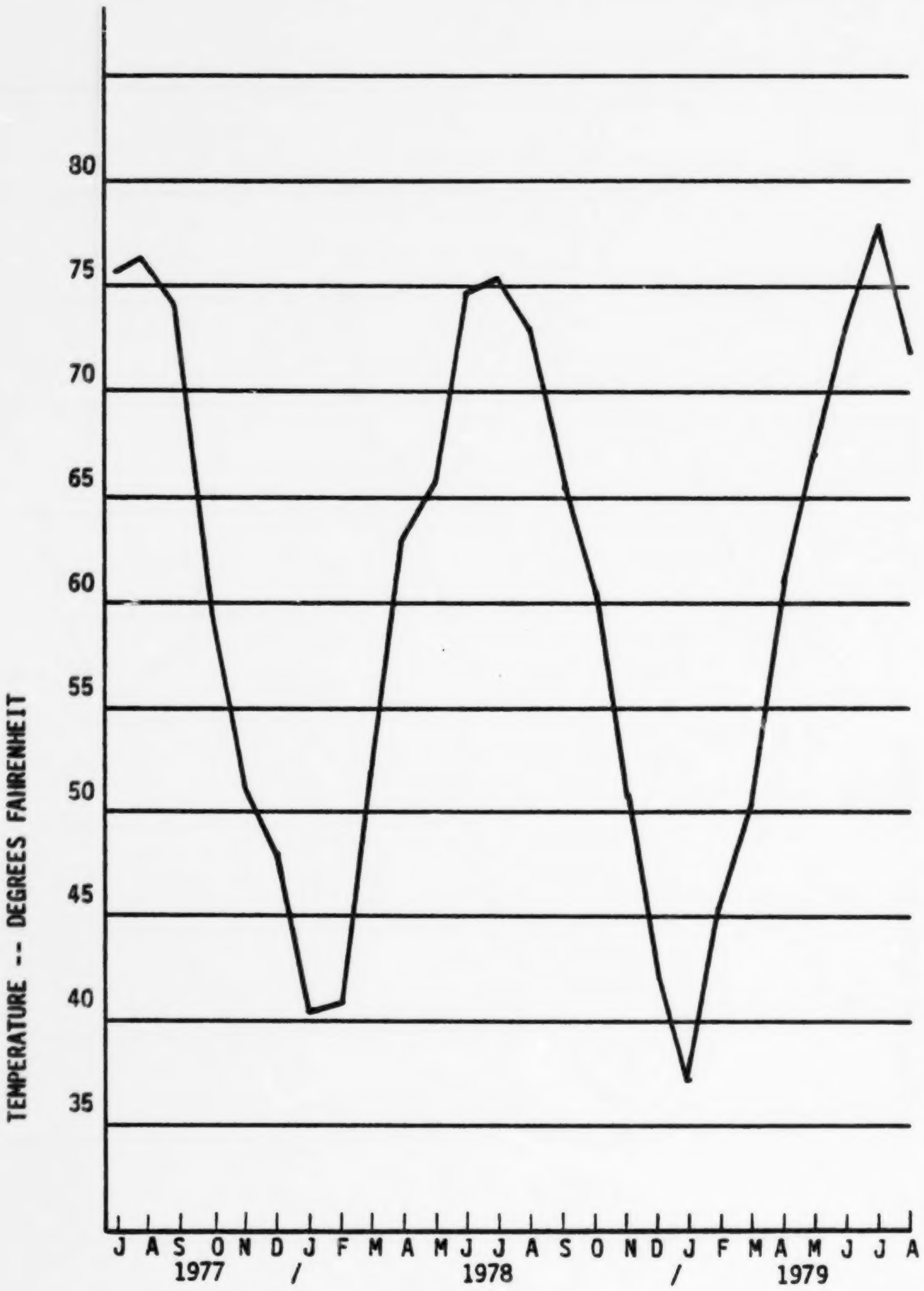

Figure 31. Temperature -- Station 8B-8D.

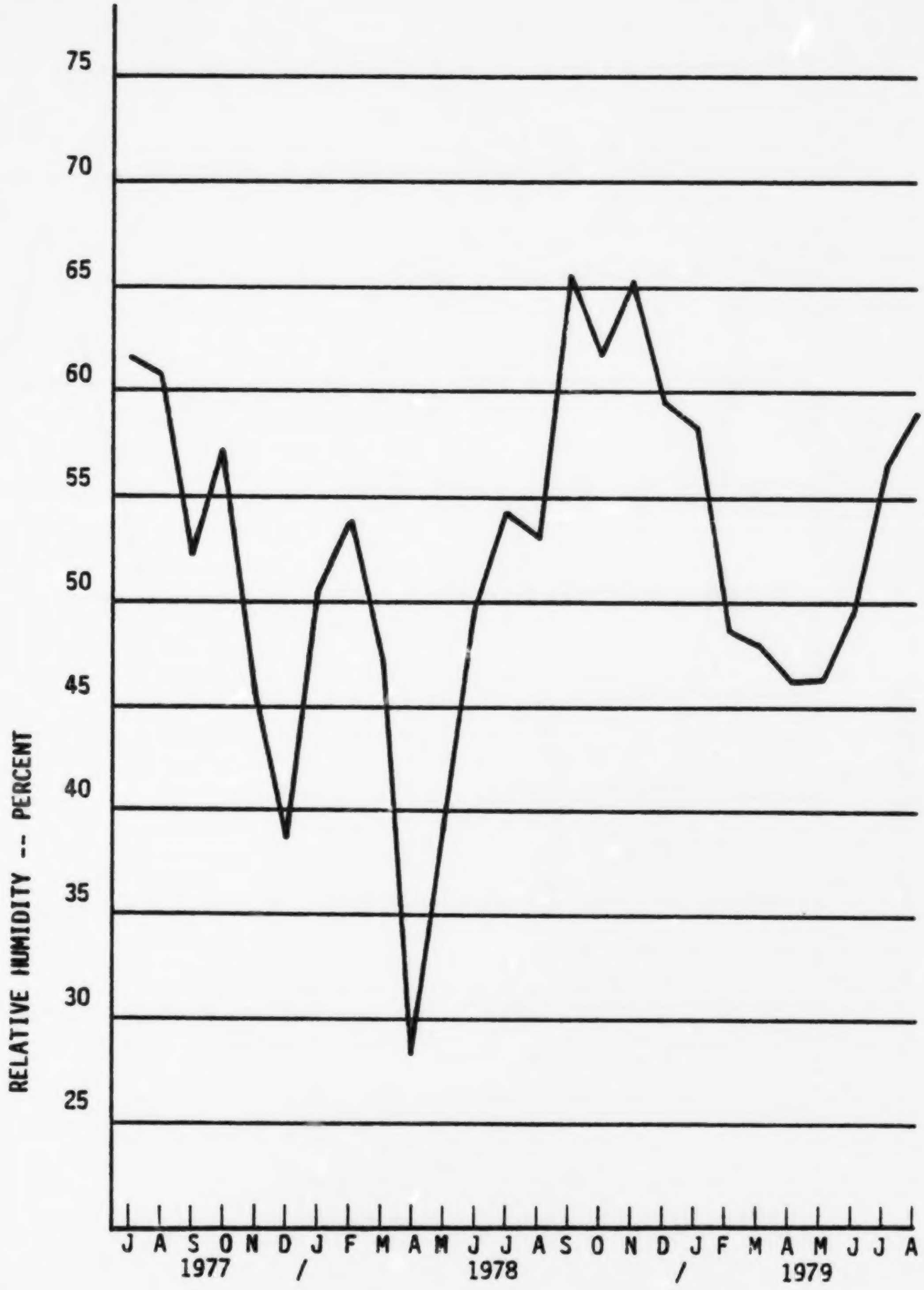

Figure 32. Relative Humidity -- Station 8B-8D.

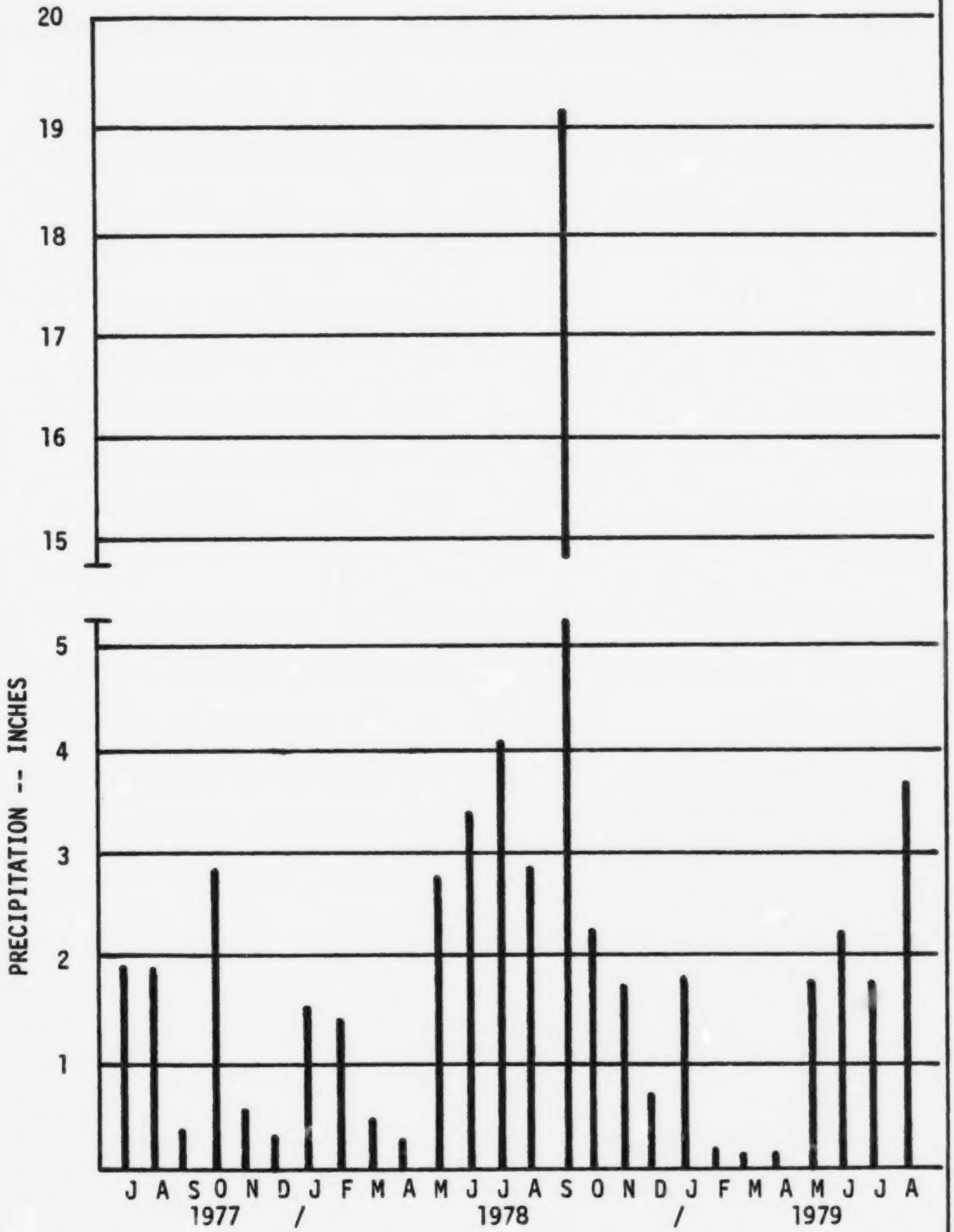

Figure 33. Precipitation -- Station WS-6.

TABLE 16. PRECIPITATION INTENSITY SUMMARY STATION WS-6

| Intensity Interval (inches/hour) | Number of Events | Frequency Percent |
|---|---|---|
| 0.00-0.25 | 252 | 78.7 |
| 0.25-0.50 | 23 | 7.2 |
| 0.50-0.75 | 15 | 4.7 |
| 0.75-1.00 | 12 | 3.8 |
| 1.00-1.50 | 13 | 4.1 |
| 1.50-2.00 | 2 | 0.6 |
| 2.00-3.00 | 1 | 0.3 |
| 3.00-4.00 | 2 | 0.6 |
| Total | 320 | 100.0 |

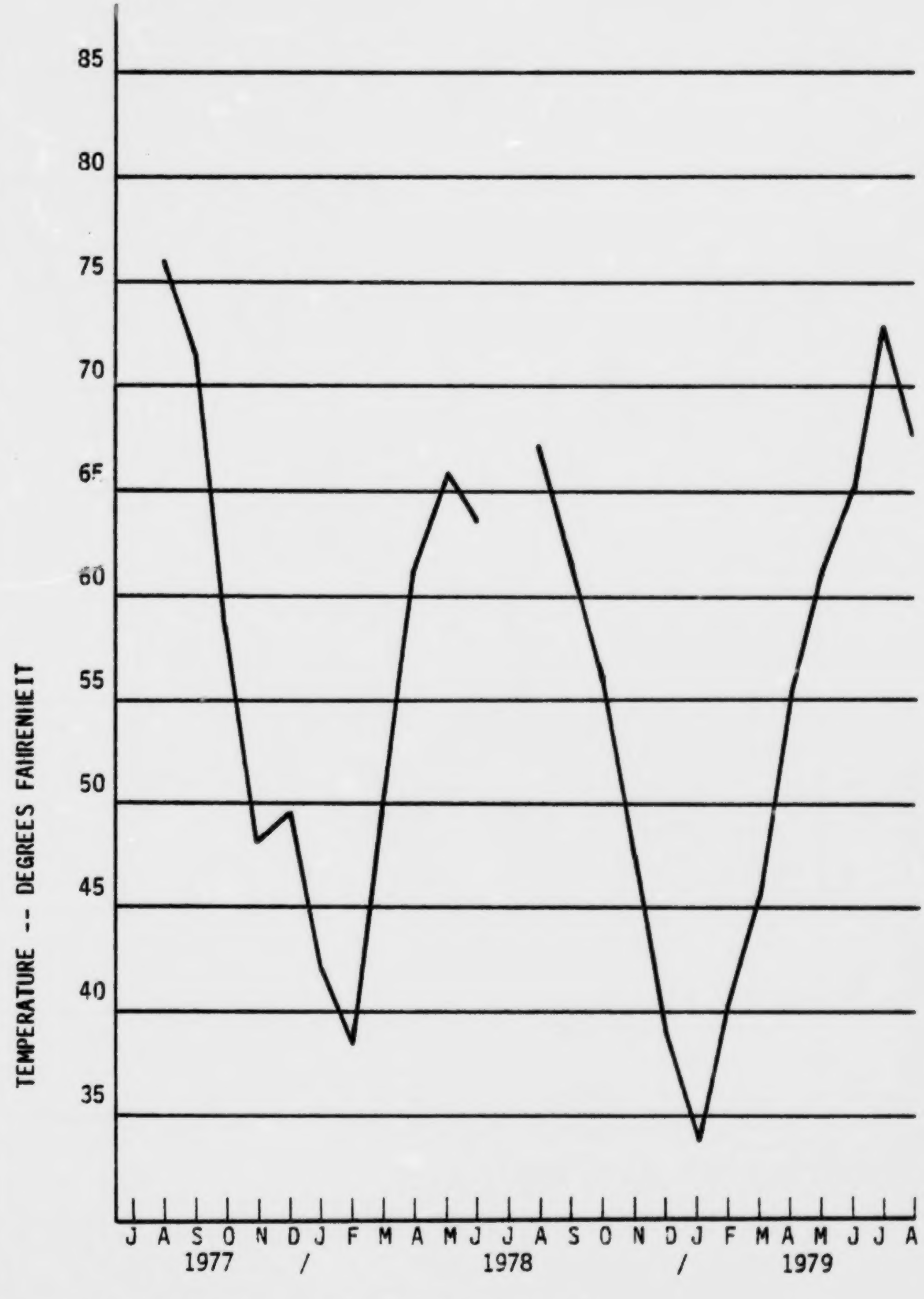

Figure 34. Temperature -- Station WS-6.

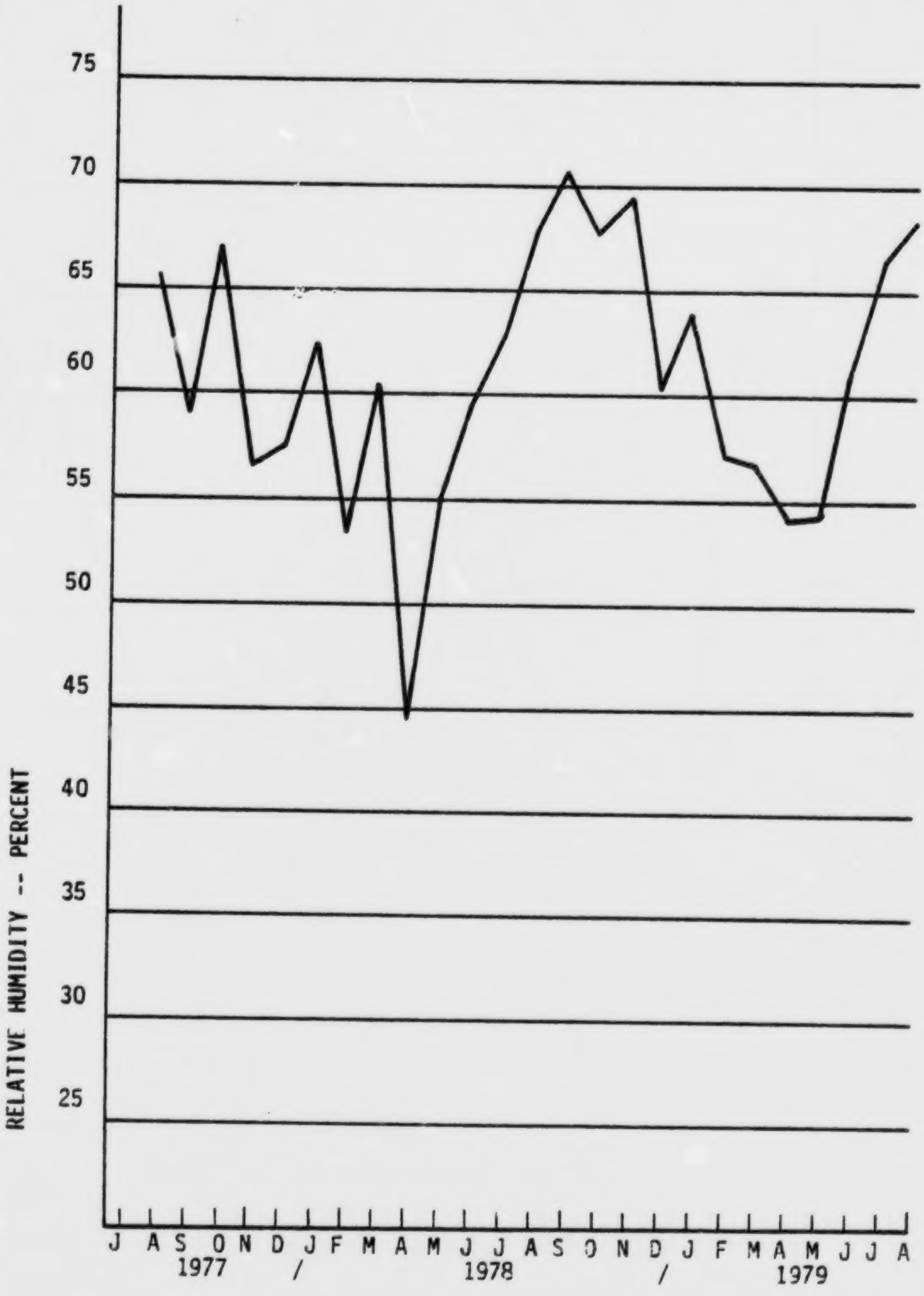

Figure 35. Relative Humidity -- Station WS-6.

numerous occasions and a low of 9% was recorded at 2000 hours on 2 January 1979.

In relation to other recording stations within the park station WS-6 ranked second in total precipitation and was the most humid site while generally being slightly cooler than station 8B-8D and slightly warmer than WS-1.

Solar radiation monthly average maximums are presented in Figure 36. Highest intensity recorded during the study period was 1.64 gram-calories per centimeter squared per minute at 1330 hours on 17 August 1978.

## STATION 10A6

Instrumentation at station 10A6 was completed in mid July 1977. The station is located at 4000 feet elevation, 31°56'33" N latitude, 104°56'22" W longitude, on the west side of the park approximately 1.6 miles east of Able's well. The site is on a slight ridge in the bajada extending westward from the west escarpment of the mountains. Surrounding vegetation is an open desert shrub community. The slope is approximately 5% with a west aspect.

Monthly precipitation totals are shown graphically in Figure 37. During the study period July 1977 through August 1979, 173 precipitation events were recorded. Table 17 presents a summary of these events by intensity intervals.

In relation to other recording stations in the park station 10A6 ranked lowest in total precipitation. Although not instrumented for temperature and humidity this site would also be the hottest and most xeric station.

## STATION BOWL

Instrumentation at Station Bowl was completed in September 1977. The station is located at 7750 feet elevation, 31°55'36" N latitude, 104°49'32" W longitude near the earthen stock tank in the Bowl area of the park. The site is on a shallow alluvial flat at the confluence of three small drainages. Construction of the earth tank has resulted in extensive modification of the site. The slope is approximately 5% with a north aspect. The vegetation immediately surrounding the site

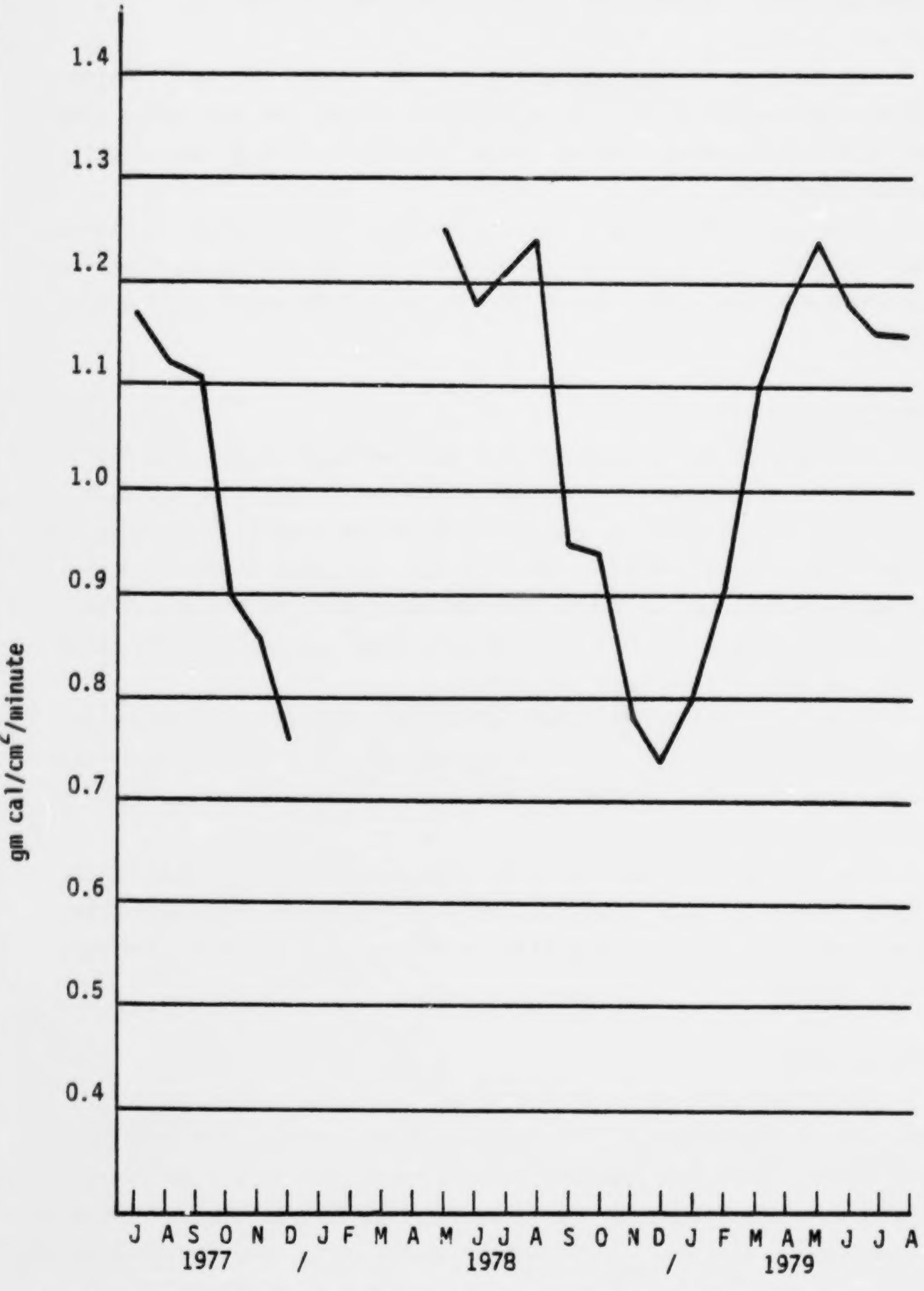

Figure 36. Average Daily Maximum Solar Radiation -- Station WS-6.

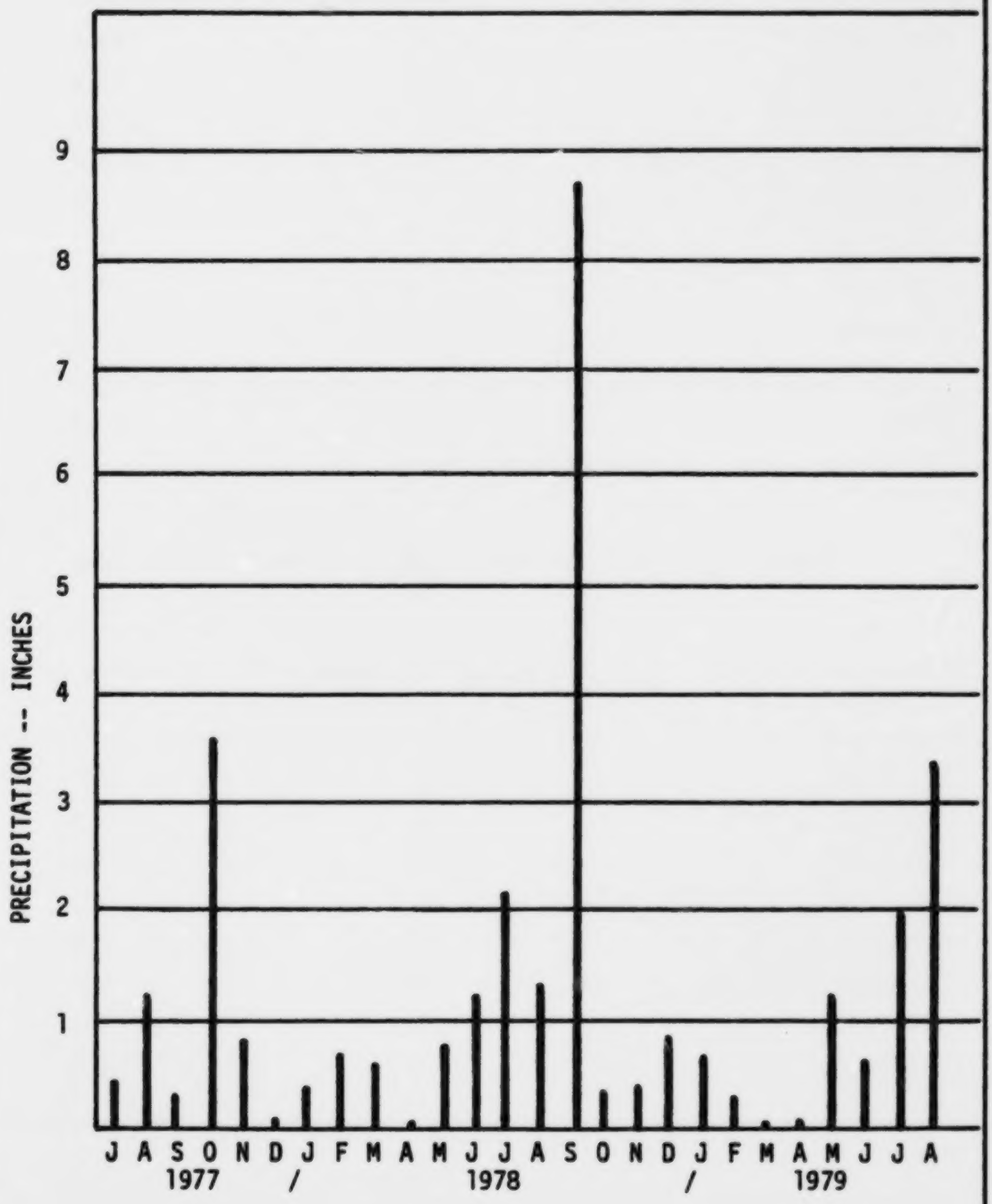

Figure 37. Precipitation -- Station 10A6.

## TABLE 17. PRECIPITATION INTENSITY SUMMARY STATION 10A6

| Intensity Interval (inches/hour) | Number of Events | Frequency Percent |
|---|---|---|
| 0.00-0.25 | 121 | 69.9 |
| 0.25-0.50 | 20 | 11.6 |
| 0.50-0.75 | 16 | 9.2 |
| 0.75-1.00 | 11 | 6.4 |
| 1.00-1.50 | 3 | 1.7 |
| 1.50-2.00 | 2 | 1.2 |
| 2.00-3.00 | 0 | 0.0 |
| 3.00-4.00 | 0 | 0.0 |
| Total | 173 | 100.0 |

## TABLE 18. PRECIPITATION INTENSITY SUMMARY STATION BOWL

| Intensity Interval (inches/hour) | Number of Events | Frequency Percent |
|---|---|---|
| 0.00-0.25 | 193 | 76.0 |
| 0.25-0.50 | 33 | 13.0 |
| 0.50-0.75 | 14 | 5.5 |
| 0.75-1.00 | 10 | 3.9 |
| 1.00-1.50 | 4 | 1.6 |
| 1.50-2.00 | 0 | 0.0 |
| 2.00-3.00 | 0 | 0.0 |
| 3.00-4.00 | 0 | 0.0 |
| Total | 254 | 100.0 |

is a grassland which encompasses less than 10 acres. The general vegetation is a coniferous forest.

Monthly precipitation totals are shown graphically in Figure 38. During the study period September 1977 through August 1979, 254 precipitation events were recorded. Table 18 presents a summary of these events by intensity intervals.

In relation to other recording stations in the park, Station Bowl ranked highest in total precipitation. Although not instrumented this site would also be the coolest and most humid station.

## ANALYSIS

In order to better understand the relationships between the five precipitation recording stations in this study, a series of correlation and regression analyses were undertaken. As a prelude to a discussion of these analyses several points need to be considered. First the site selection for station installation was somewhat predetermined based upon locations within or near the intensive study watersheds. Secondly within this framework an attempt was made to locate the stations so as to obtain a wide range of elevational and geographical locations. Third, observations during the study period seem to indicate that storm patterns and storm tracks are associated with the topographic structure of the park in general. Specifically numerous observations during convection storm activity seemed to indicate that storms tended to move along the axis of the eastern escarpment and that simultaneous storms on the west and east sides of the park were rather unusual events.

The first analysis of precipitation data involved the use of monthly total precipitation for the period September 1977 through August 1979. Table 19 presents the correlation coefficient matrix for this data set as well as the probabilities for $>|R|$ under the null hypothesis of $R = 0$. The values of R were unexpectedly high in all cases apparently indicating rather strong correlations among the various recording stations, at least in terms of monthly total precipitation.

Further examination of the relationships among stations was undertaken using regression analysis to develop simple linear regression models among the stations. Such models were expected to be useful to predict missing data values in the event of instrument malfunctions at

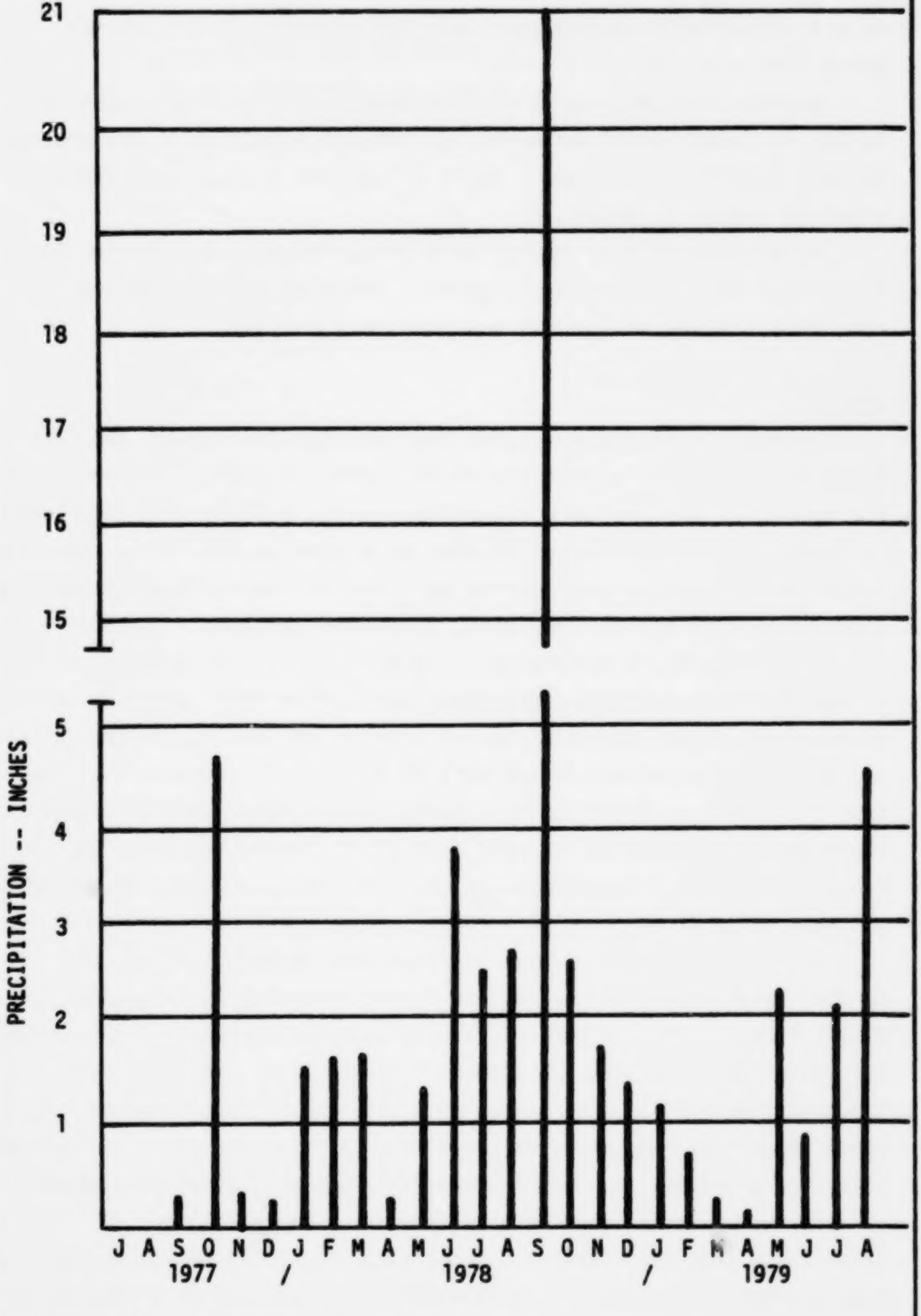

Figure 38. Precipitation -- Station Bowl.

## TABLE 19. CORRELATION COEFFICIENTS AND PROBABILITY > |R| UNDER Ho :: R = 0; N = 24

| | 10A6 | Bowl | 6 | 8B-8D | 1 |
|---|---|---|---|---|---|
| 10A6 | 1.0000<br>-- | | | | |
| Bowl | 0.9475<br>0.0001 | 1.0000<br>-- | | | |
| 6 | 0.9312<br>0.0001 | 0.9823<br>0.0001 | 1.0000<br>-- | | |
| 8B-8D | 0.9270<br>0.0001 | 0.9924<br>0.0001 | 0.9847<br>0.0001 | 1.0000<br>-- | |
| 1 | 0.9555<br>0.0001 | 0.9880<br>0.0001 | 0.9786<br>0.0001 | 0.9792<br>0.0001 | 1.0000<br>-- |

## TABLE 20. SELECTED REGRESSION MODELS FOR PRECIPITATION STATIONS WITHIN THE PARK. $\hat{Y} = a + bx$ (N = 24)

| Independent Variable Station | Dependent Variable Station | $R^2$ | $S_{yx}$ | a | b |
|---|---|---|---|---|---|
| 1 | Bowl | 0.98 | 0.68 | .09± .16 | 1.33± .04 |
| 1 | 10A6 | 0.91 | 0.56 | .25± .13 | 0.55± .04 |
| 1 | 8B-8D | 0.96 | 0.67 | -.08± .16 | 0.98± .04 |
| 6 | 8B-8D | 0.97 | 0.57 | -.08± .16 | 0.84± .03 |
| 6 | 1 | 0.96 | 0.68 | -.12± .16 | 0.82± .04 |
| 8B-8D | Bowl | 0.98 | 0.55 | .02± .13 | 1.33± .04 |
| 8B-8D | 6 | 0.97 | 0.68 | .17± .16 | 1.15± .04 |
| 8B-8D | 1 | 0.96 | 0.66 | -.01± .16 | 0.97± .04 |
| Bowl | 10A6 | 0.90 | 0.60 | .24± .14 | 0.40± .03 |

specific sites. Additionally the most useful models would be those which used stations 1, 6, or 8B-8D as independent variables to predict the other stations. Stations 1, 6, and 8B-8D are located where park service personnel are regularly present and can conveniently monitor and maintain the meteorological equipment. There are also some historical records available in the immediate vicinity of station 8B-8D which could provide a tentative basis for extrapolation if desired.

Table 20 presents the regression models selected to meet the requirements discussed above.

The selection of "best" regression models was based on a review of all possible models and a review of the statistics involved which generally are considered to summarize nearly all that is revealed about a relationship through regression analysis.

First, the coefficient of determination ($R^2$) indicated the proportion of the variance in the values of the dependent variable which can be accounted for from the concomitant variation in the values of the independent variable. The usual interpretation in comparisons is that the higher the $R^2$ variable the "better" the relationship for models with equal sample sizes.

The second statistic of interest is b, the slope of the regression line or coefficient of regression. This value indicates the average number of units of increase or decrease in the dependent variable which occur with each unit change in the value of the independent variable.

Finally the standard error of the estimate $S_{yx}$ indicates how closely the estimated values agree with the observed values for the dependent variable. Generally speaking, the smaller the value of $S_{yx}$ the "better" the particular model in terms of the agreement between estimated and observed values.

For the purposes of this study each of these statistics can have value in the final interpretation of the relationships involved. Since values of b were expected to vary based on station location the primary emphasis in selecting "best" models was directly toward a comparison of $R^2$ and $S_{yx}$ values.

Close examination of the regression models reveals that although the values of the coefficient of determination ($R^2$) are exceptionally high, the values of the standard error of the estimate ($S_{yx}$) are not particularly small when compared to the magnitude of the observations. This apparent anomoly leads to further investigation of the relationships involved. During the 24-month study period, exceptionally heavy precipitation occurred in September 1978. Apparently the inclusion of monthly totals, from this month, which were several times greater than the other observations creates a unique arithmetic situation in regression analysis resulting in an unusually high sum of squares value attributable to the model. It was therefore decided to reanalyze the data set using only 23 months of data omitting the unusually high values from September 1978. Table 21 presents the correlation coefficient matrix for the reduced data set and the probabilities for >|R| under the null hypothesis of R = 0. Notice that the R values remain highly significant in all cases. Table 22 presents regression models from the reduced data set selected to meet the criteria discussed previously. The changed analysis results in a somewhat smaller set of "best" models which give a "better" fit in the most common range of precipitation values. Further observations in the heavy precipitation value range may enable construction of models for that data range in the future.

A similar series of correlation and regression analyses were undertaken utilizing the park stations and the longer term record stations outside the park. Table 23 presents "best" regression models for this data set. These relationships are not generally as strong as the relationships among the stations within the park. Until such time as additional data permits further analyses and possibly refinement of the relationships, specific predictions should be made very cautiously.

## TABLE 21. CORRELATION COEFFICIENTS AND PROBABILITY > |R| UNDER Ho :: R = 0; N = 23

| | 10A6 | Bowl | 6 | 8B-8D | 1 |
|---|---|---|---|---|---|
| 10A6 | 1.0000<br>-- | | | | |
| Bowl | 0.8416<br>0.0001 | 1.0000<br>-- | | | |
| 6 | 0.7273<br>0.0001 | 0.8200<br>0.0001 | 1.0000<br>-- | | |
| 8B-8D | 0.7104<br>0.0001 | 0.9173<br>0.0001 | 0.8455<br>0.0001 | 1.0000<br>-- | |
| 1 | 0.8731<br>0.0001 | 0.8794<br>0.0001 | 0.7928<br>0.0001 | 0.7892<br>0.0001 | 1.0000<br>-- |

## TABLE 22. SELECTED REGRESSION MODELS FOR PRECIPITATION STATIONS WITHIN THE PARK. $\hat{Y} = a + bx$ (N = 23)

| Independent Variable Station | Dependent Variable Station | $R^2$ | $S_{yx}$ | a | b |
|---|---|---|---|---|---|
| 1 | Bowl | 0.77 | 0.65 | .34± .21 | 1.12± .13 |
| 1 | 10A6 | 0.76 | 0.49 | -.04± .15 | .81± .10 |
| 6 | 8B-8D | 0.71 | 0.55 | .16± .19 | .68± .09 |
| 8B-8D | Bowl | 0.84 | 0.55 | .14± .19 | 1.23± .12 |

TABLE 23. SELECTED REGRESSION MODELS FOR PRECIPITATION STATIONS INSIDE AND OUTSIDE THE PARK. $\hat{Y} = a + bx$

| Independent Variable Station | Dependent Variable Station | $R^2$ | $S_{yx}$ | a | b | n |
|---|---|---|---|---|---|---|
| Cornudus | Bowl | 0.54 | 0.94 | .83± .27 | .93± .19 | 22 |
| Cornudus | 8B-8D | 0.55 | 0.67 | .61± .19 | .67± .14 | 22 |
| Cornudus | 6 | 0.43 | 0.97 | .90± .27 | .76± .20 | 22 |
| Carlsbad | 6 | 0.35 | 1.05 | .82± .36 | .64± .20 | 21 |
| Carlsbad | 8B-8D | 0.34 | 0.85 | .63± .29 | .51± .16 | 21 |
| FAA Carlsbad | 8B-8D | 0.33 | 0.84 | .76± .24 | .47± .14 | 21 |

# CHAPTER VI VEGETATION

As indicated in the introduction chapter, one of the objectives of this research was to study the relationships among soils, vegetation, parent material, climate, geomorphic surfaces, topography and current land use, and to relate these factors to hydrology, erosion, sedimentation and chemical water quality. This chapter deals with the vegetation of the park. By providing initial plant community information, future investigators will have a data base to study these relationships, and to detect any changes which may occur due to recreational development of the park.

Christian and Stewart (1968) stated "that the natural vegetation integrates the various factors of the environment and is therefore a good expression of these factors." With this in mind, we have mapped the major plant communities of the watersheds selected for intensive study. Plant communities were mapped using the site concept of plant ecology. A site is defined as "an area of land having a combination of edaphic, climatic, topographic and natural biotic factors that is significantly different from adjacent areas. These environmental areas are considered as units for purposes of discussion, investigation and management. Changes from one site to another represent significant differences in potential forage production and/or differences in management required for proper land use" (Huss, 1964). Range sites are differentiated on the basis of significant differences in kinds or proportions of plants making up the climax community or significant differences in production or both (Shiflet, 1973).

The methods used were based on these concepts. Areas of similar site characteristics (groundcover, slope, soils, topography, elevation, aspect) were defined as a site. A site was relatively homogeneous with regard to these characteristics, and often one or two of the characteristics were diagnostic of the site as a whole. A site also supported the same general vegetation, which is to say that the dominant trees, shrubs and understory species were generally similar throughout the site.

Within a site, a "typical" plant community was usually described. This community can be regarded as the typical expression of the site. However, each site often supported several plant communities and/or variations of these communities, due to variations in general site characteristics. Plant communities within a site differed in kinds and/or proportions of species characterizing the community, while variations of a community were recognized on the basis of different kinds and/or amounts of species of lesser importance in the community. Communities were named according to the dominant overstory species, both with regard to species composition and overstory; and dominant understory species. When a particular overstory species lent a distinctive aspect to the vegetation, even though it may not have contributed a significant amount to the species composition or overstory, it was included in the community name. When the vegetation was unusually variable and occurred in a mosaic pattern it was designated as a community complex (Mueller-Dombois and Ellenberg, 1974). In these complexes, individual communities were usually too small to delineate for mapping purposes, and were thus treated descriptively.

A modification of the Step-Point procedure described by Evans and Love (1957) was employed as the sampling technique. Over 400 transects were sampled in the intensive study watersheds. Using aerial photographs and personal reconnaissance, areas of similar slope, elevation, topography and vegetation were selected and sampled. A sample consisted of a line transect (50 points) perpendicular to the contour. Along this transect, a point at the toe of the right foot was projected onto the ground at each pace. Groundcover at the point was classified into six categories: litter, bare ground, small rock (smaller than 12 inches in diameter), large rock, cryptogam and vegetation (basal cover).

These characteristics, along with slope, aspect, elevation and topography are referred to as site characteristics. Also at each point, the nearest plant species was recorded; this data provided species composition information. Overstory above each point was recorded by species at 0-6, 6-20 and greater than 20 ft. levels. In the data totals presented, Carex spp. are grouped with grass totals, both trees and shrubs are included in shrub totals, and overstory included both trees and shrubs. Elevation means are means from the transects; elevation ranges are for the site or community as a whole and were taken from topographic maps. Insofar as possible, site names were based on topographic features. All scientific nomenclature follows Correll and Johnston (1970). Bunting's (1978) work provided a basic flora of the area, and common names follow his designations.

## WATERSHED 1

Much of the northern part of Watershed 1 is made up of sedimentary rock with slopes ranging from 5 to 50% or greater and mountain shrub vegetation. The southern part of the watershed is also made up of sedimentary rock, but has slopes generally greater than 50%, with densely growing trees along the streams and north-facing slopes. Valley floors support dense mountain shrub vegetation, with slopes between 5 and 50%. The upper eastern escarpment is sedimentary rock with mountain shrub vegetation and a few scattered trees (Fish, et al., 1977). Bunting (1978) stated that the wide variation in aspect, slope, soil development and available moisture resulted in a complex association of shrub dominated communities throughout much of the area. Soils were generally rocky, shallow, moderate in organic matter and variable in texture.

Fourteen sites, three inclusions, twenty-six communities and one community complex were found in Watershed 1 (Tables 24, 25; Figure 39).

### DRY, VERY STONY SLOPE (50%)--SITE

The Dry, Very Stony Slope (50%) site was found primarily in northern and middle Upper Dog Canyon at elevations ranging from 6300 to 7400 ft. (Table 26, Figure 40). The site was characterized between the main channel of the watershed and its western boundary in the

## TABLE 24. SITES AND COMMUNITIES OF WATERSHED 1

| Site | Community | Map Symbol |
|---|---|---|
| Dry, Very Stony Slope (50%) | Smallseed sacahuista-blue threeawn-sideoats grama | 1A |
| | Variation of above community | 1B |
| | Smallseed sacahuista-sideoats grama | 1C |
| | Smallseed sacahuista-New Mexico muhly-littleawn needlegrass-sideoats grama | 1D |
| | Smallseed sacahuista-New Mexico muhly | 1E |
| | Desert rose-New Mexico muhly-pine muhly | 1F |
| Heavily Oaken Slope (49%) | Wavyleaf oak-New Mexico muhly | 2A |
| Dry, Oaken, Stony Slope (46%) | Wavyleaf oak-smallseed sacahuista-sideoats grama-blue threeawn | 3A |
| | Wavyleaf oak-smallseed sacahuista-New Mexico muhly-sideoats grama | 3B |
| Dry, Stony Slope (58%) | Mountain mahogany-wavyleaf oak-New Mexico muhly | 4A |
| Open Ridgetop | Smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass | 5A |
| (Inclusion) | Pinyon pine-finestem needlegrass | 6A |
| | Smallseed sacahuista-plains lovegrass | 6B |
| (Inclusion) | Ponderosa pine-New Mexico muhly-littleawn needlegrass | 7A |
| Dry, Rocky Slope (21%) | Smallseed sacahuista-mountain mahogany-pine muhly-plains lovegrass | 8A |

TABLE 24 (continued)

| Site | Community | Map Symbol |
|---|---|---|
| Valley Floor | Alligator juniper-gray oak-sideoats grama | 10A |
| Meadow | Finestem needlegrass | 9A |
| Escarpment | Wavyleaf oak-pine muhly | 11A |
| | Wavyleaf oak-smallseed sacahuista-pine muhly-bull muhly | 11B |
| | Not sampled | 11C |
| Wooded Ridgetop | Ponderosa pine-alligator juniper-pine muhly complex | 12A |
| | Wavyleaf oak-mountain mahogany-plains lovegrass-pine muhly | 12B |
| | Pinyon pine-New Mexico muhly | 12C |
| Steep Wooded Slope (49%) | Douglas fir-New Mexico muhly | 13A |
| | Ponderosa pine-wavyleaf oak-New Mexico muhly | 13B |
| Steep Intermediately Wooded Slope | Alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly | 14A |
| Steep Wooded Northeastern Slope (41%) | Ponderosa pine-*Quercus*-New Mexico muhly | 15A |
| Densely Wooded Ridgetop | Southwestern white pine-alligator juniper-pringle needlegrass | 16A |

## TABLE 25. VEGETATIVE COMPOSITION WATERSHED 1

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| 1A | 11.9 | 376 | .59 |
| 1B | 2.1 | 66 | .10 |
| 1C | 1.2 | 38 | .06 |
| 1D | 0.5 | 16 | .02 |
| 1E | 1.9 | 60 | .09 |
| 1F | 0.1 | 3 | .01 |
| 2A | 12.8 | 406 | .64 |
| 3A | 0.3 | 9 | .01 |
| 3B | 5.4 | 171 | .27 |
| 4A | 11.8 | 374 | .59 |
| 5A | 8.9 | 281 | .44 |
| 6A | 0.5 | 16 | .02 |
| 6B | 0.1 | 3 | .01 |
| 7A | 0.2 | 6 | .01 |
| 8A | 2.7 | 85 | .13 |
| 9A | 1.4 | 44 | .07 |
| 10A | 5.5 | 174 | .27 |
| 11A | 1.4 | 44 | .07 |
| 11B | 2.6 | 82 | .13 |
| 11C | 5.0 | 158 | .25 |
| 12A | 1.9 | 60 | .09 |
| 12B | 0.9 | 28 | .04 |
| 12C | 3.4 | 107 | .17 |
| 12D | 1.9 | 60 | .09 |
| 13A | 6.0 | 190 | .30 |
| 13B | 2.7 | 85 | .13 |
| 14A | 3.5 | 111 | .17 |
| 15A | 1.4 | 44 | .07 |
| 16A | 2.0 | 63 | .10 |
|  | 100.0 | 3,160 | 4.94* |

* Includes only area within National Park Boundary

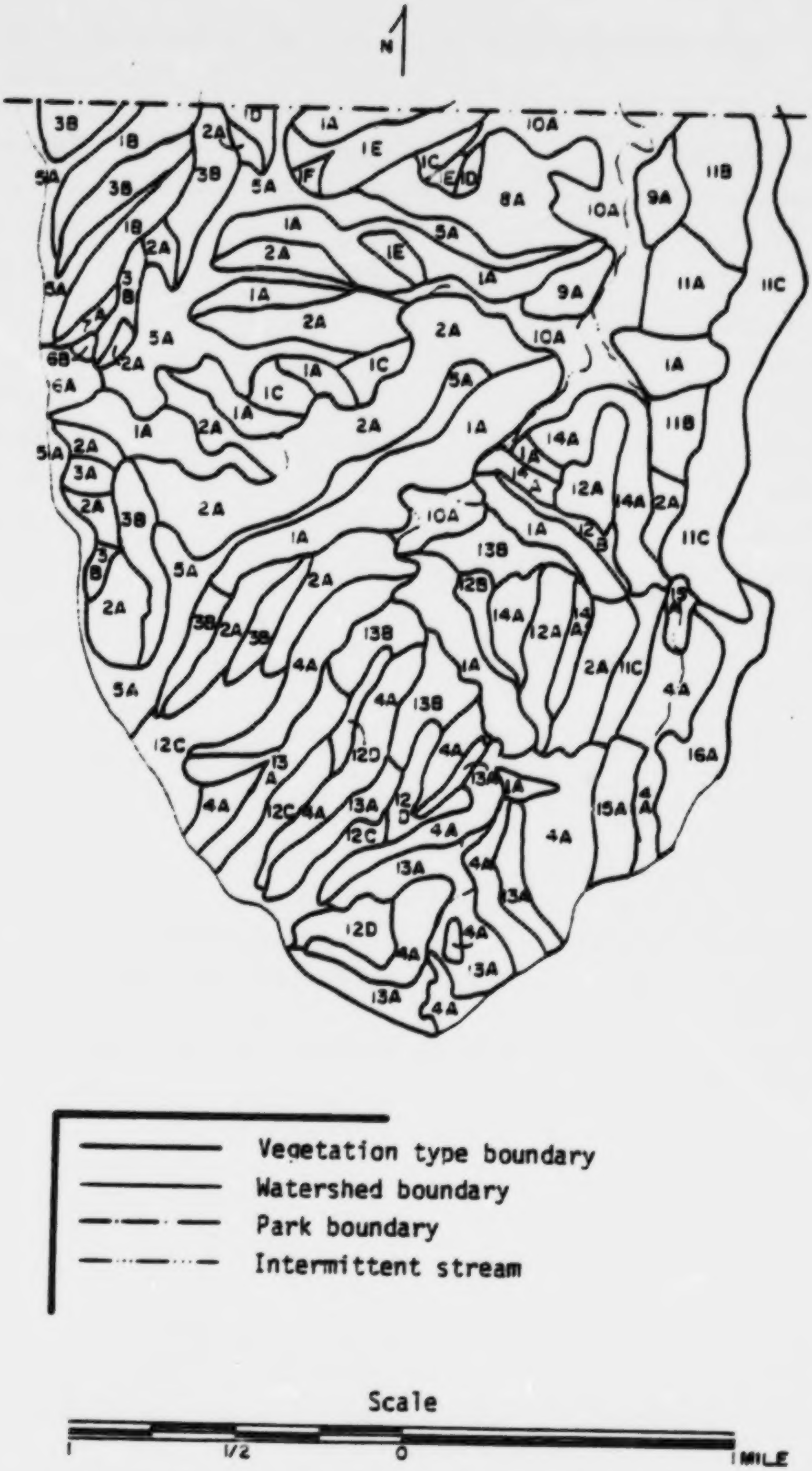

Figure 39. Vegetation Types Watershed 1.

TABLE 26. SITE CHARACTERISTICS OF THE DRY, VERY STONY SLOPE (50%) SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 6850 | 6300-7400 |
| Slope (%) | 50 | 40-67 |
| Ground cover (%) | | |
| Vegetation | 15 | 6-30 |
| Litter | 19 | 2-40 |
| Small rock | 55 | 39-72 |
| Large rock | 4 | 0-12 |
| Bare ground | 7 | 0-18 |
| Cryptogam | 0 | -- |
| Overstory (%) | | |
| 0-6' | 14 | 0-26 |
| 6-20' | 0 | -- |
| > 20' | 0 | -- |
| Total | 14 | 0-26 |
| Grasses (%) | 72 | 44-94 |
| Forbs (%) | 13 | 0-42 |
| Shrubs (%) | 15 | 2-28 |

Data based on transects 14-18, 20-22, 27, 93-105, 108, 109, 132, 137, 138, 174-176, 180

Aspects: Southern, eastern, western, southeastern, southwestern, northwestern, northern

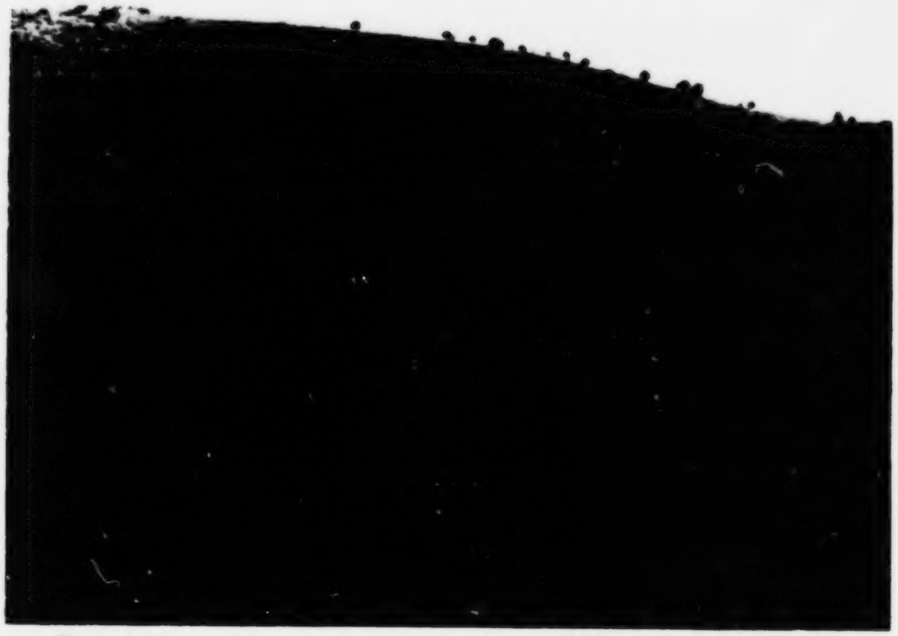

Figure 40. Dry, Very Stony Slope (50%) Site; typical expression of the smallseed sacahuista-blue threeawn-sideoats grama community.

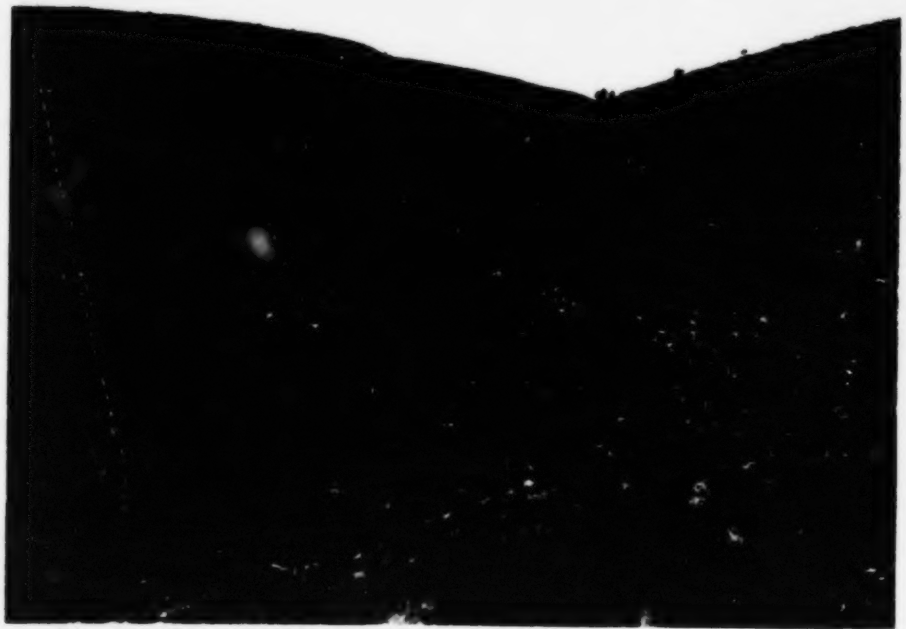

Figure 41. Smallseed sacahuista-sideoats grama community (Dry, Very Stony Slope (50%) Site). (Background: Heavily Oaken Slope (49%) Site; wavyleaf oak-New Mexico muhly community.)

Pitchfork and adjacent canyons. Although the site is typically found on southern exposures, it also occurred on some eastern, western, southeastern, southwestern and northern aspects, and on one protected northeastern aspect. The relative proportions of small rock (55%), litter (19%) and vegetative groundcover (15%) were characteristic of the site.

The major southern aspects of the site supported a smallseed sacahuista-blue threeawn-sideoats grama community (Table 27, Figure 40). Blue threeawn (*Aristida glauca*) (20%) and sideoats grama (*Bouteloua curtipendula*) (15%) were the dominant grasses. In most areas, curlyleaf muhly (*Muhlenbergia setifolia*), New Mexico feathergrass (*Stipa neomexicana*) and littleawn needlegrass (*Stipa lobata*) were also common, comprising up to 32%, 22% and 32%, respectively, of the species composition. However, in some areas, these species were relatively less important. Smallseed sacahuista (*Nolina micrantha*) was the dominant shrub, both with regard to species composition (5%) and overstory (9%). Mountain mahogany (*Cercocarpus montanus* var. *paucidentatus*), smooth sotol (*Dasylirion leiophyllum*), mariola parthenium (*Parthenium incanum*) and algarita (*Berberis trifoliata*) were also common shrubs. There was a variety of forbs, the most common of which were plains blackfoot (*Melampodium leucanthum*) and babywhite-aster (*Leucelene ericoides*). Five percent of the vegetation was made up of a combination of plains blackfoot, babywhite-aster, *Polygala* spp. and hedeoma (*Hedeoma costatum* var. *pulchellum*).

Because this was a relatively extensive site, there were several plant communities and variations of these communities. On the higher elevation southern exposures, littleawn needlegrass (32%) and New Mexico muhly (*Muhlenbergia pauciflora*) (12%) were more common, with less blue threeawn (0%), curlyleaf muhly (0%) and New Mexico feathergrass (4%). However, smallseed sacahuista and sideoats grama remained important. Because there was no change in aspect, this area represents only a higher elevation phase of the smallseed sacahuista-blue threeawn-sideoats grama community.

Eastern and southeastern aspects around 7000 ft. in Trail Canyon were dominated in the overstory by smallseed sacahuista (12%). However, there was slightly more mountain mahogany and wavyleaf oak (*Quercus undulata*), and less smooth sotol than in the smallseed sacahuista-blue

TABLE 27. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE TYPICAL EXPRESSION OF THE SMALLSEED SACAHUISTA-BLUE THREEAWN-SIDEOATS GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6800 | 6300-7100 | | | | | | | | |
| Slope (%) | 49 | 43-56 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 18 | 10-30 | | | | | | | | |
| Litter | 14 | 4-28 | | | | | | | | |
| Small rock | 60 | 52-72 | | | | | | | | |
| Large rock | 4 | 0-10 | | | | | | | | |
| Bare ground | 4 | 0-10 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 17 | 10-26 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| . Total | 17 | 10-26 | | | | | | | | |
| Aristida glauca--blue threeawn | | | 20 | 0-50 | | | | | | |
| Bouteloua curtipendula-sideoats grama | | | 15 | 6-22 | | | | | | |
| Muhlenbergia setifolia--curlyleaf muhly | | | 12 | 0-22 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 11 | 2-32 | | | | | | |
| Stipa neomexicana--New Mexico feathergrass | | | 11 | 0-22 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 4 | 0-12 | | | | | | |
| Muhlenbergia emersleyi--bull muhly | | | 3 | 0-8 | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 2 | 0-12 | | | | | | |
| Nolina micrantha--smallseed sacahuista | | | 5 | 2-8 | 9 | 2-14 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 2 | 0-4 | 4 | 0-8 | | | | |
| Dasylirion leiophyllum--smooth sotol | | | 1 | 0-2 | 2 | 0-4 | | | | |
| Parthenium incanum--mariola parthenium | | | 1 | 0-6 | | | | | | |
| Quercus undulata--wavyleaf oak | | | 1 | 0-6 | < 1 | 0-2 | | | | |
| Berberis trifoliata--algarita | | | < 1 | 0-2 | 1 | 0-6 | | | | |

Data based on transects 14-18, 95, 96, 105, 109, 174, 180

Aspects: Southern

threeawn-sideoats grama community. Sideoats grama (17%) dominated the understory, but there was slightly less blue threeawn, littleawn needlegrass and curlyleaf muhly, and more New Mexico feathergrass, plains lovegrass (Eragrostis lugens) and litter, than in the typical smallseed sacahuista-blue threeawn-sideoats grama community. Nevertheless, these areas are considered a phase of the smallseed sacahuista-blue threeawn sideoats grama community, occurring on a soil with probably a stronger argiustoll influence than the typical expression of the community (which was characterized on a soil with a stronger calciustoll influence).

The smallseed sacahuista-sideoats grama community (Table 28, Figure 41) was found on eastern aspects at 6880 ft. Pine muhly (Muhlenbergia dubia) (9%), plains lovegrass (8%), bull muhly (Muhlenbergia emersleyi) (8%), New Mexico muhly (8%) and littleawn needlegrass (7%) were also important grasses. In these areas, blue threeawn and New Mexico feathergrass were not found. Overstory increased to 21% because of the addition of wavyleaf oak (2%) and desert ceanothus (Ceanothus greggii) (2%). Also, there was more litter (31%), more shrubs (21%) and less vegetative groundcover (8%) than in the smallseed sacahuista-blue threeawn-sideoats grama community of the southern aspects. In addition, wavyleaf oak made up 8% of the species composition. However, smallseed sacahuista was still the dominant overstory species. Prairie bluets (Hedyotis nigricans) (3%) was the most common forb, although there were many other species present, including babywhite-aster, plains blackfoot, Hawkweed wildbuckwheat (Eriogonum hieracifolium) and hairy evolvulus (Evolvulus nuttalianus).

Western aspects at approximately 6850 ft. had more bare ground (11%) and less overstory than the typical smallseed sacahuista-blue threeawn-sideoats grama community of the southern aspects of the site. These areas supported a smallseed sacahuista-New Mexico muhly-littleawn needlegrass-sideoats grama community (Table 29). In this community, New Mexico feathergrass, blue threeawn and curlyleaf muhly were less important than in the smallseed sacahuista-blue threeawn-sideoats grama community, and there were small amounts of wavyleaf oak. James nailwort (Paronychia jamesii), prickleaf gilia (Gilia rigidula), Polygala spp. and Hawkweed wildbuckwheat were common forbs.

TABLE 28. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-SIDEOATS GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6880 | 6400-7000 | | | | | | | | |
| Slope (%) | 53 | 50-55 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 8 | 6-10 | | | | | | | | |
| Litter | 31 | 30-32 | | | | | | | | |
| Small rock | 48 | 42-54 | | | | | | | | |
| Large rock | 5 | 4-6 | | | | | | | | |
| Bare ground | 8 | 4-12 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 21 | 20-22 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 21 | 20-22 | | | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 18 | 18 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 9 | 6-12 | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 8 | 8 | | | | | | |
| *Muhlenbergia emersleyi*--bull muhly | | | 8 | 0-16 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 8 | 6-10 | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 7 | 4-10 | | | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 6 | 4-8 | 14 | 14 | | | | |
| *Quercus undulata*--wavyleaf oak | | | 8 | 4-12 | 2 | 2 | | | | |
| *Ceanothus greggii*--desert ceanothus | | | 3 | 2-4 | 3 | 2-4 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 2 | 2 | 2 | 2 | | | | |
| *Muhlenbergia setifolia*--curlyleaf muhly | | | 5 | 2-8 | | | | | | |

Data based on transects 175, 176

Aspects: Eastern

TABLE 29. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-NEW MEXICO MUHLY-LITTLEAWN NEEDLEGRASS-SIDEOATS GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6850 | 6400-6900 | | | | | | | | |
| Slope (%) | 46 | 42-48 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 10 | 6-12 | | | | | | | | |
| Litter | 24 | 18-30 | | | | | | | | |
| Small rock | 50 | 46-58 | | | | | | | | |
| Large rock | 5 | 2-6 | | | | | | | | |
| Bare ground | 11 | 8-14 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 12 | 6-18 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 12 | 6-18 | | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 15 | 0-28 | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 15 | 12-16 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 11 | 8-12 | | | | | | |
| *Stipa neomexicana*--New Mexico feathergrass | | | 6 | 0-10 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 5 | 2-12 | | | | | | |
| *Aristida glauca*--blue threeawn | | | 5 | 0-14 | | | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 7 | 2-10 | 7 | 4-8 | | | | |
| *Quercus undulata*--wavyleaf oak | | | 3 | 0-6 | 3 | 0-7 | | | | |

Data based on transects 132, 137, 138

Aspects: Western

Northern to eastern aspects at 6760 to 6920 ft. in the region of Stateline Canyon also belonged to the Dry, Very Stony Slope (50%) site. However, these aspects had less overstory (9%) and more forbs (21%) in the vegetation. The proportion of shrubs (14%) remained constant.

The smallseed sacahuista-New Mexico muhly community was found on these northern to eastern aspects (Table 30). There were several variations of this community. Throughout the community, smallseed sacahuista was the dominant shrub, comprising 7% of the species composition and 4% of the overstory, and New Mexico muhly was the dominant grass, comprising 29% of the vegetation. Wavyleaf oak contributed 4% to the species composition and 2% to the overstory on northern aspects, but did not occur in the samples on eastern and northeastern aspects. Mountain mahogany was absent on the northern exposures. Longstalk greenthread (*Thelesperma longipes*) (10%) and James nailwort (3%) were the most common forbs. On northern and eastern aspects, pine muhly was important, making up 13% of the vegetation. This species was relatively unimportant on northeastern aspects. Plains blackfoot (7%) was the most common forb on eastern aspects, and was absent from the northern aspects. There was little longstalk greenthread on eastern aspects. Sideoats grama was important on both eastern and northeastern aspects, comprising 9% of the species composition. In addition, there was 6% plains lovegrass and smaller amounts of blue threeawn and curlyleaf muhly. Plains lovegrass was much less common, and blue threeawn and curlyleaf muhly were not found, on northern exposures. Little bluestem (*Schizachyrium scoparium*) (10%) was common on northern and northeastern aspects, but infrequent on eastern aspects. James nailwort (8%) and hedeoma (8%) were the most common forbs on northeastern aspects.

There were significant changes in the overstory of a small but distinct community dominated by desert rose (*Rosa stellata*) in the overstory (5%) and species composition (17%). This inclusion was a desert rose-New Mexico muhly-pine muhly community (Table 31). New Mexico muhly (29%) and pine muhly (19%) were the most common grasses. There was less smallseed sacahuista, both in the species composition (2%) and overstory (1%), and wavyleaf oak was infrequent.

TABLE 30. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-NEW MEXICO MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6820 | 6400-6900 | | | | | | | | |
| Slope (%) | 54 | 46-67 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 14 | 8-20 | | | | | | | | |
| Litter | 15 | 2-24 | | | | | | | | |
| Small rock | 58 | 44-72 | | | | | | | | |
| Large rock | 6 | 2-12 | | | | | | | | |
| Bare ground | 7 | 2-18 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 9 | 0-16 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 9 | 0-16 | | | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 29 | 14-54 | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 11 | 4-20 | | | | | | |
| Schizachyrum scoparium--little bluestem | | | 8 | 0-18 | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 6 | 0-10 | | | | | | |
| Stipa lobata-littleawn needlegrass | | | 4 | 0-12 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 3 | 0-6 | | | | | | |
| Nolina micrantha--smallseed sacahuista | | | 7 | 4-10 | 4 | 0-10 | | | | |
| Quercus undulata--wavyleaf oak | | | 4 | 0-8 | 2 | 0-8 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 1 | 0-6 | 1 | 0-8 | | | | |

Data based on transects 93, 94, 100-104, 108

Aspects: Northern to eastern

TABLE 31. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE DESERT ROSE-NEW MEXICO MUHLY-PINE MUHLY COMMUNITY

|  | Site Characteristics |  | Species Composition % |  | Overstory % |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | 0-6' |  | 6-20' |  | > 20' |  |
|  | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6900 | 6600-6900 |  |  |  |  |  |  |  |  |
| Slope (%) | 56 | 56 |  |  |  |  |  |  |  |  |
| Ground cover (%) |  |  |  |  |  |  |  |  |  |  |
| Vegetation | 17 | 16-18 |  |  |  |  |  |  |  |  |
| Litter | 19 | 8-30 |  |  |  |  |  |  |  |  |
| Small rock | 50 | 40-62 |  |  |  |  |  |  |  |  |
| Large rock | 3 | 0-10 |  |  |  |  |  |  |  |  |
| Bare ground | 11 | 6-14 |  |  |  |  |  |  |  |  |
| Cryptogam | 0 | -- |  |  |  |  |  |  |  |  |
| Overstory (%) |  |  |  |  |  |  |  |  |  |  |
| 0-6' | 11 | 6-16 |  |  |  |  |  |  |  |  |
| 6-20' | 0 | -- |  |  |  |  |  |  |  |  |
| > 20' | 0 | -- |  |  |  |  |  |  |  |  |
| Total | 11 | 6-16 |  |  |  |  |  |  |  |  |
| *Muhlenbergia pauciflora*--New Mexico muhly |  |  | 29 | 20-34 |  |  |  |  |  |  |
| *Muhlenbergia dubia*--pine muhly |  |  | 19 | 18-22 |  |  |  |  |  |  |
| *Bouteloua curtipendula*--sideoats grama |  |  | 11 | 8-14 |  |  |  |  |  |  |
| *Eragrostis lugens*--plains lovegrass |  |  | 5 | 2-8 |  |  |  |  |  |  |
| *Stipa lobata*--littleawn needlegrass |  |  | 3 | 0-6 |  |  |  |  |  |  |
| *Rosa stellata*--desert rose |  |  | 17 | 16-18 | 9 | 6-14 |  |  |  |  |
| *Nolina micrantha*--smallseed sacahuista |  |  | 2 | 0-4 | 1 | 0-4 |  |  |  |  |

Data based on transects 97-99

Aspects: Northeastern

## HEAVILY OAKEN SLOPE (49%)--SITE

The Heavily Oaken Slope (49%) (Table 32, Figure 42) site was found in northern Upper Dog Canyon on northeastern to northwestern aspects in the same general region of the watershed as the Dry, Very Stony Slope (50%) site. There was more than twice as much litter (48%) and overstory (41%), and half as much small rock ground cover (29%) on the Heavily Oaken Slope (49%) site as on the Dry, Very Stony Slope (50%) site (Figure 43). Because of the often dense overstory, there was also less vegetative ground cover (5%) on the Heavily Oaken Slope (49%) site. Shrubs made up twice as much of the species composition on the Heavily Oaken Slope (49%) site as on the Dry, Very Stony Slope (50%) site. Amount of forbs, however, was similar on the two sites.

The major plant community on Heavily Oaken Slope (49%) sites was the wavyleaf oak-New Mexico muhly community (Table 32, Figure 43). The abundance of wavyleaf oak, both in species composition (23%) and overstory (35%), was a characteristic feature of this community. This species often grew in dense mottes, comprising up to 38% of the species composition and 56% of the overstory. In some topographic positions, pinyon pine (Pinus edulis) and ponderosa pine (Pinus ponderosa) were present as scattered individuals. New Mexico muhly was the most common understory species (30%), and comprised up to as much as 52% of the species composition in one area. Littleawn needlegrass (8%), sideoats grama (4%) and Carex spp. (5%) were also present. Blue threeawn, New Mexico feathergrass and curlyleaf muhly and pine muhly were seldom found. There was a variety of forbs, the most common of which were James nailwort, prickleaf gilia and hedeoma, which combined to make up 5% of the vegetation.

## DRY, OAKEN, STONY SLOPE (46%)--SITE

In the drier areas of southeastern to eastern aspects at 6800-7200 ft., and on northwestern to southwestern and eastern to western aspects at 6600-7400 ft., were areas with site characteristics intermediate between the Dry, Very Stony Slope (50%) site and the Heavily Oaken Slope (49%) site. The vegetation found in these areas was also generally related to the vegetation found on both of these sites. These areas constituted the Dry, Oaken, Stony Slope (46%) site (Table 33).

TABLE 32. SITE CHARACTERISTICS OF THE HEAVILY OAKEN SLOPE (49%) SITE AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-NEW MEXICO MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7040 | 6400-7400 | | | | | | | | |
| Slope (%) | 49 | 40-68 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 9 | 0-18 | | | | | | | | |
| Litter | 48 | 36-70 | | | | | | | | |
| Small rock | 29 | 12-47 | | | | | | | | |
| Large rock | 8 | 0-16 | | | | | | | | |
| Bare ground | 6 | 0-20 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 41 | 22-61 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 41 | 22-61 | | | | | | | | |
| Grasses (%) | 57 | 22-61 | | | | | | | | |
| Forbs (%) | 10 | 0-28 | | | | | | | | |
| Shrubs (%) | 33 | 16-56 | | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 30 | 4-52 | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 8 | 0-20 | | | | | | |
| *Carex* spp.--sedge | | | 5 | 0-18 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 4 | 0-10 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 3 | 0-8 | | | | | | |
| *Schizachyrium scoparium*--little bluestem | | | 2 | 0-10 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 2 | 0-8 | | | | | | |
| *Quercus undulata*--wavyleaf oak | | | 23 | 8-38 | 35 | 12-56 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 4 | 0-10 | 4 | 0-12 | | | | |
| *Chrysothamnus spathulatus*--rabbitbrush | | | 2 | 0-12 | < 1 | 0-2 | | | | |
| *Rosa stellata*--desert rose | | | < 1 | 0-10 | < 1 | 0-6 | | | | |

TABLE 32. Continued

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| *Ceanothus greggii*--desert ceanothus | | | < 1 | 0-6 | < 1 | 0-4 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | < 1 | 0-4 | < 1 | 0-8 | | | | |

Data based on transects 1, 3-5, 29, 133, 139, 144, 145, 152, 155, 156, 159-162, 178, 179, 182-184

Aspects: Northwestern to northeastern

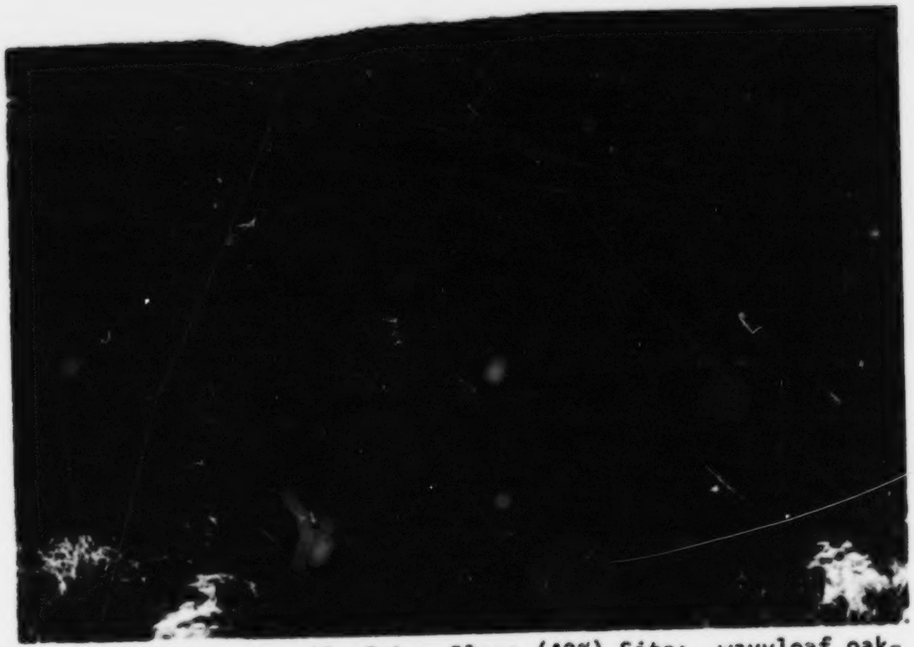

Figure 42. Heavily Oaken Slope (49%) Site; wavyleaf oak-New Mexico muhly community (middle of photograph). Immediate foreground: Open Ridgetop Site; smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community.

Figure 43. Right side: Dry, Very Stony Slope (50%) Site; smallseed sacahuista-blue threeawn-sideoats grama community.
Left side: Heavily Oaken Slope (49%) Site; wavyleaf oak-New Mexico muhly community.

## TABLE 33. SITE CHARACTERISTICS OF DRY, OAKEN, STONY SLOPE (46%) SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 7100 | 6600-7400 |
| Slope (%) | 46 | 34-55 |
| Ground cover (%) | | |
| Vegetation | 11 | 4-20 |
| Litter | 32 | 14-44 |
| Small rock | 47 | 34-64 |
| Large rock | 5 | 0-20 |
| Bare ground | 5 | 0-14 |
| Cryptogam | 0 | -- |
| Overstory (%) | | |
| 0-6' | 24 | 12-36 |
| 6-20' | 1 | 0-8 |
| > 20' | 0 | -- |
| Total | 24 | 12-36 |
| Grasses (%) | 68 | 42-82 |
| Forbs (%) | 12 | 0-24 |
| Shrubs (%) | 20 | 8-38 |

Data based on transects 28, 134, 135, 140, 142, 143, 153, 154, 157, 158, 164, 165, 169-173, 190-192

Aspects: Eastern, western, southeastern, southwestern, northwestern, northeastern

The wavyleaf oak-smallseed sacahuista-sideoats grama-blue threeawn community occurred in the drier areas of southeastern to eastern aspects at 6900-7200 ft. (Table 34). This community differed from the smallseed sacahuista-sideoats grama community of the Dry, Very Stony Slope (50%) site, also found on eastern aspects but at lower elevations, because of the presence of more wavyleaf oak in the overstory and the appearance of blue threeawn (11%) and New Mexico feathergrass (9%) in the understory. There was also much less pine muhly (2%) in the wavyleaf oak-smallseed sacahuista-sideoats grama-blue threeawn community. New Mexico muhly, bull muhly and plains lovegrass, relatively common in the smallseed sacahuista-sideoats grama community, were less common in the wavyleaf oak-smallseed sacahuista-sideoats grama-blue threeawn community. The wavyleaf oak-smallseed sacahuista-sideoats grama-blue threeawn community differed from the smallseed sacahuista-blue threeawn-sideoats grama community (of the southern exposures of the Dry, Very Stony Slope (50%) site) because it had much more wavyleaf oak, both in the species composition and overstory.

The wavyleaf oak-smallseed sacahuista-New Mexico muhly-sideoats grama community was found on northwestern to southwestern and eastern to western aspects at 6600-7400 ft. (Table 35). Throughout the community, New Mexico muhly (22%) and sideoats grama (12%) were the dominant grasses; and wavyleaf oak (7% in the species composition and 10% in the overstory) and smallseed sacahuista (5% in the species composition and 7% in the overstory) were the dominant shrubs. There were several minor variations of this community. On eastern to east northeastern aspects at 7050 ft., blue threeawn (7%) was a common understory species, and curlyleaf muhly (0%), little bluestem (0%), New Mexico feathergrass (0%) and Carex spp. (0.4%) were infrequent or absent. Desert rose was usually an important shrub, making up 3% of the species composition and 4% of the overstory. Desert ceanothus was infrequent or absent. On the western aspects at 6980 ft., there was less blue threeawn and slightly more curlyleaf muhly (3%), little bluestem (3%) and Carex spp. (3%). In the overstory, desert rose was not found, and desert ceanothus made up 2% and 3% of the species composition and overstory, respectively. Pine muhly (7%), littleawn needlegrass (9%) and plains lovegrass (6%) were similar in both variations of the community. On northwestern to southwestern aspects at 7260 ft., sideoats grama was less common (5%),

TABLE 34. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMALLSEED SACAHUISTA-SIDEOATS GRAMA-BLUE THREEAWN COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7120 | 6900-7200 | | | | | | | | |
| Slope (%) | 41 | 34-44 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 14 | 12-16 | | | | | | | | |
| Litter | 29 | 24-34 | | | | | | | | |
| Small rock | 44 | 42-46 | | | | | | | | |
| Large rock | 7 | 2-12 | | | | | | | | |
| Bare ground | 6 | 4-12 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 24 | 12-34 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 24 | 12-34 | | | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 17 | 8-28 | | | | | | |
| Aristida glauca--blue threeawn | | | 11 | 6-20 | | | | | | |
| Stipa neomexicana--New Mexico feathergrass | | | 9 | 4-20 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 8 | 4-16 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 5 | 2-12 | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 4 | 0-6 | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 2 | 0-2 | | | | | | |
| Quercus undulata--wavyleaf oak | | | 6 | 0-10 | 6 | 2-12 | | | | |
| Nolina micrantha--smallseed sacahuista | | | 6 | 2-10 | 9 | 2-14 | | | | |
| Ceanothus greggii--desert ceanothus | | | 4 | 2-8 | 4 | 2-6 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 1 | 0-2 | 2 | 0-4 | | | | |

Data based on transects 153, 154, 157, 158

Aspects: Southeastern to eastern

TABLE 35. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMALLSEED SACAHUISTA-NEW MEXICO MUHLY-SIDEOATS GRAMA COMMUNITY
(COMPOSITE DATA OF THE VARIATIONS MENTIONED IN TEXT)

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7100 | 6600-7400 | | | | | | | | |
| Slope (%) | 47 | 39-55 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 11 | 4-20 | | | | | | | | |
| Litter | 33 | 14-44 | | | | | | | | |
| Small rock | 46 | 34-64 | | | | | | | | |
| Large rock | 5 | 0-20 | | | | | | | | |
| Bare ground | 5 | 0-14 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 23 | 12-36 | | | | | | | | |
| 6-20' | 1 | 0-8 | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 24 | 12-36 | | | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 22 | 8-44 | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 12 | 0-28 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 9 | 0-20 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 9 | 0-20 | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 6 | 0-18 | | | | | | |
| Aristida glauca--blue threeawn | | | 3 | 0-18 | | | | | | |
| Carex spp.--sedge | | | 1 | 0-7 | | | | | | |
| Quercus undulata--wavyleaf oak | | | 7 | 0-13 | 10 | 2-18 | | | | |
| Nolina micrantha--smallseed sacahuista | | | 5 | 0-12 | 7 | 2-15 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 2 | 0-6 | 2 | 0-8 | | | | |
| Ceanothus greggii--desert ceanothus | | | 2 | 0-8 | 2 | 0-10 | | | | |
| Rosa stellata--desert rose | | | < 1 | 0-8 | 1 | 0-14 | | | | |

Data based on transects 28, 134, 135, 140, 142, 143, 164, 165, 169-173, 190-192

Aspects: Eastern, western, southwestern, northwestern with more plains lovegrass (17%) and littleawn needlegrass (10%). Pine muhly, blue threeawn, New Mexico feathergrass and little bluestem were infrequent or absent. Also, both desert ceanothus and desert rose were infrequent or absent, and mountain mahogany made up 2% and 3% of the species composition and overstory, respectively. In the drier areas of this variation, sideoats grama was more common; wavyleaf oak made up less of the overstory; and more mountain mahogany was found.

## DRY, STONY SLOPE (58%)--SITE

The steep eastern to southern aspects of the ridges which extended northward from McKittrick Ridge had site characteristics roughly similar to the Dry, Oaken, Stony Slope (46%) site. However, these aspects were steeper (58%) and had less litter (22%) and more large rock (16%). These areas constituted the Dry, Stony Slope (58%) site, which also supported different vegetation, the mountain mahogany-wavyleaf oak-New Mexico muhly community (Table 36, Figure 44). Twenty-seven percent of the vegetation was made up of shrubs, and there was a wide variety of species. Mountain mahogany was the most common species, making up 7% of the species composition and 11% of the overstory. Desert ceanothus, wavyleaf oak, smooth sotol, smallseed sacahuista and silktassel (Garrya ovata) were also present, in amounts ranging from 2-5% in the species composition and 1-4% in the overstory. New Mexico muhly (22%) dominated the understory. Also present were littleawn needlegrass (11%), plains lovegrass (10%) and bull muhly, pine muhly and sideoats grama, each contributing 4-5%. There was a wide variety of forbs, making up 14% of the vegetation. Common species included hedeoma (2%), plains blackfoot (1%), Allium spp. (1%) and noseburn (Tragia ramosa) (1%), among many others.

This community was similar to the wavyleaf oak-smallseed sacahuista-New Mexico muhly-sideoats grama community of the Dry, Oaken, Stony Slope (46%) site because of the abundance of New Mexico muhly. However, they were two distinct communities because of the increased abundance of mountain mahogany and smooth sotol; the overall increased relative proportion of shrubs in the vegetation; and the decreased abundance of sideoats grama in the mountain mahogany-wavyleaf oak-New Mexico muhly community.

TABLE 36. SITE CHARACTERISTICS OF THE DRY, STONY SLOPE (58%) SITE AND SPECIES COMPOSITION OF THE MOUNTAIN MAHOGANY-WAVYLEAF OAK-NEW MEXICO MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7320 | 6700-7600 | | | | | | | | |
| Slope (%) | 58 | 38-70 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 11 | 8-14 | | | | | | | | |
| Litter | 22 | 16-32 | | | | | | | | |
| Small rock | 44 | 34-60 | | | | | | | | |
| Large rock | 16 | 4-30 | | | | | | | | |
| Bare ground | 7 | 2-12 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 22 | 12-40 | | | | | | | | |
| 6-20' | 1 | 0-2 | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 23 | 12-40 | | | | | | | | |
| Grasses (%) | 59 | 48-70 | | | | | | | | |
| Forbs (%) | 14 | 6-22 | | | | | | | | |
| Shrubs (%) | 27 | 16-32 | | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 22 | 12-28 | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 11 | 8-16 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 10 | 2-16 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 5 | 2-8 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 5 | 0-8 | | | | | | |
| *Muhlenbergia emersleyi*--bull muhly | | | 5 | 0-8 | | | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 7 | 4-12 | 11 | 2-16 | | | | |
| *Quercus undulata*--wavyleaf oak | | | 5 | 2-10 | 3 | 0-4 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 3 | 2-4 | 4 | 2-6 | | | | |

TABLE 36. Continued

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| *Nolina micrantha*--smallseed sacahuista | | | 4 | 0-6 | 1 | 0-4 | | | | |
| *Ceanothus greggii*--desert ceanothus | | | 2 | 0-6 | 2 | 0-4 | | | | |
| *Garrya ovata*--silktassel | | | 2 | 0-4 | 2 | 0-2 | | | | |

Data based on transects 87, 88, 91, 92, 125-127

Aspects: Eastern to southeastern

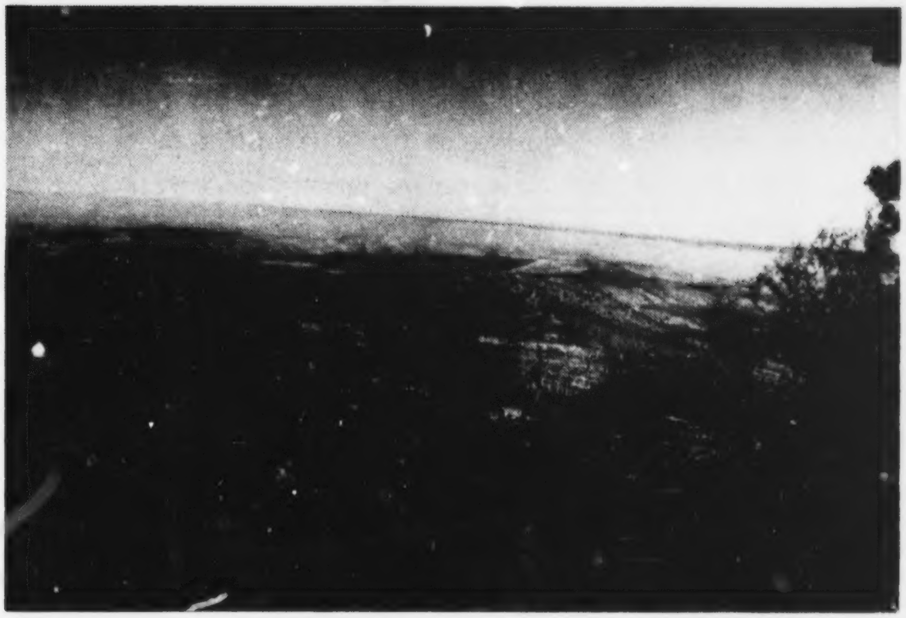

Figure 44. Dry, Stony Slope (58%) Site; mountain mahogany-wavyleaf oak-New Mexico muhly community (ridges in lower left, midground framed by two pinyon pine trees).

Figure 45. Open Ridgetop Site; smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community.

Although this community had approximately similar site characteristics as the wavyleaf oak-smallseed sacahuista-sideoats grama-blue threeawn community of the Dry, Oaken, Stony Slope (46%) site, its species composition was widely divergent. New Mexico muhly was infrequent (4%) in the wavyleaf oak-smallseed sacahuista-sideoats grama-blue threeawn community, but was the dominant grass in the mountain mahogany-wavyleaf oak-New Mexico muhly community. The mountain mahogany-wavyleaf oak-New Mexico muhly community had much less sideoats grama, and New Mexico feathergrass and blue threeawn did not occur. Also, there was more mountain mahogany and less smallseed sacahuista in the mountain mahogany-wavyleaf oak-New Mexico muhly community. Finally, silktassel and smooth sotol did not occur in the samples in the wavyleaf oak-smallseed sacahuista-sideoats grama-blue threeawn community, but were present in the mountain mahogany-wavyleaf oak-New Mexico muhly community.

## OPEN RIDGETOP--SITE

Open ridgetops throughout northern Upper Dog Canyon were found at elevations ranging from 6600 to 7600 ft. They had no dominant aspect and slopes were negligible. These areas comprised the Open Ridgetop site. The Open Ridgetop site was similar to the Dry, Very Stony Slope (50%) site in that there was more small rock ground cover (39%) than litter (28%), but the difference in amount between these two classes of ground cover was less in the Open Ridgetop site. Amount of overstory in the Open Ridgetop site and the Dry, Very Stony Slope (50%) site was very similar, and both of these sites had much less overstory than the Heavily Oaken Slope (49%) site. Also, amounts of grasses, forbs and shrubs was similar on Dry, Very Stony Slope (50%) sites and Open Ridgetop sites.

The major plant community of the Open Ridgetop site was the smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community (Table 37, Figure 45). Plains lovegrass (14%) and New Mexico feathergrass (12%) were the most common grasses. Other important species included blue threeawn (11%), sideoats grama (11%), littleawn needlegrass (7%) and wolftail (Lycurus phleoides) (6%). There was a variety of forbs, the most common of which was James nailwort (4%).

TABLE 37. SITE CHARACTERISTICS OF THE OPEN RIDGETOP SITE AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-MOUNTAIN MAHOGANY-PLAINS LOVEGRASS-NEW MEXICO FEATHERGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7030 | 6600-7600 | | | | | | | | |
| Slope (%) | 3 | 0-5 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 17 | 8-30 | | | | | | | | |
| Litter | 28 | 12-42 | | | | | | | | |
| Small rock | 40 | 16-62 | | | | | | | | |
| Large rock | 7 | 0-22 | | | | | | | | |
| Bare ground | 8 | 0-22 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 16 | 6-32 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 16 | 6-32 | | | | | | | | |
| Grasses (%) | 76 | 60-94 | | | | | | | | |
| Forbs (%) | 11 | 2-26 | | | | | | | | |
| Shrubs (%) | 13 | 4-22 | | | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 14 | 4-24 | | | | | | |
| Stipa neomexicana--New Mexico feathergrass | | | 11 | 0-26 | | | | | | |
| Aristida glauca--blue threeawn | | | 11 | 0-32 | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 10 | 2-24 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 7 | 0-16 | | | | | | |
| Lycurus phleoides--wolftail | | | 6 | 0-38 | | | | | | |
| Carex spp.--sedge | | | 5 | 0-14 | | | | | | |
| Muhlenbergia setifolia--curlyleaf muhly | | | 3 | 0-10 | | | | | | |
| Nolina micrantha--smallseed sacahuista | | | 6 | 0-12 | 7 | 0-14 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 4 | 0-12 | 6 | 0-14 | | | | |

TABLE 37. Continued

|  | Site Characteristics |  | Species Composition % |  | Overstory % |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | 0-6' |  | 6-20' |  | > 20' |  |
|  | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| *Ceanothus greggii*--desert ceanothus |  |  | 1 | 0-8 | < 1 | 0-8 |  |  |  |  |
| *Quercus undulata*--wavyleaf oak |  |  | < 1 | 0-2 | < 1 | 0-4 |  |  |  |  |

Data based on transects 6-10, 23, 30, 48, 49, 106, 107, 163, 166-168, 177, 181

Aspects: None

Plains blackfoot, babywhite-aster and Euphorbia spp. combined to make up another 2% of the species composition.

This community was similar to the smallseed sacahuista-blue threeawn-sideoats grama community of the southern aspects of the Dry, Very Stony Slope (50%) site in that blue threeawn, sideoats grama, New Mexico feathergrass and littleawn needlegrass were all important grasses. However, Carex spp. and wolftail were infrequent or absent in the smallseed sacahuista-blue threeawn-sideoats grama community, whereas they comprised 5% and 6%, respectively, of the species composition of the smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community. Also, plains lovegrass was very important in the smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community, but only made up 4% of the species composition in the smallseed sacahuista-blue threeawn-sideoats grama community. Finally, curlyleaf muhly (3%) was relatively unimportant in the smallseed sacahuista-mountain mahogany-plains lovegrass community, but made up 12% of the species composition of the smallseed sacahuista-blue threeawn-sideoats grama community.

At the higher elevations, there appeared to be less blue threeawn in the smallseed sacahuista-mountain mahogany-plains lovegrass community. Wavyleaf oak was often infrequent or absent throughout the site. New Mexico agave (Agave neomexicana) was present in small amounts, and there were occasional scattered Juniperus spp. and pinyon pine along the tops of the ridges throughout the site.

On the ridgetop separating West Dog Canyon from Dog Canyon, in the location where the Pitchfork (Marcus) Trail crosses this ridge, was an area of distinctive vegetation, treated here as an inclusion. Ninety-five percent of the vegetation was made up of grasses, and in this respect, the area was similar to the Meadow site (discussed below). However, there was less litter (67%) and more small rock (9%), large rock (1%) and bare ground (5%). Also, there was both tree and shrub overstory, totaling 28%.

The pinyon pine-finestem needlegrass community (Table 38, Figure 46) was found in this area. Smallseed sacahuista and small amounts of cholla (Opuntia imbricata), apacheplume (Fallugia paradoxa), desert rose

TABLE 38. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PINYON PINE-FINESTEM NEEDLEGRASS COMMUNITY (INCLUSION)

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7200 | 7150-7250 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 18 | 18 | | | | | | | | |
| Litter | 67 | 60-74 | | | | | | | | |
| Small rock | 9 | 4-14 | | | | | | | | |
| Large rock | 1 | 0-2 | | | | | | | | |
| Bare ground | 5 | 2-8 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 18 | 10-26 | | | | | | | | |
| 6-20' | 10 | 4-16 | | | | | | | | |
| > 20 | 0 | -- | | | | | | | | |
| Total | 28 | 14-42 | | | | | | | | |
| Grasses (%) | 95 | 92-98 | | | | | | | | |
| Forbs (%) | 2 | 0-4 | | | | | | | | |
| Shrubs (%) | 3 | 2-4 | | | | | | | | |
| *Stipa tenuissima*--finestem needlegrass | | | 48 | 34-62 | | | | | | |
| *Muhlenbergia repens*--mat muhly | | | 19 | 16-20 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 14 | 2-26 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 3 | 2-4 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 3 | 2-4 | | | | | | |
| *Pinus edulis*--pinyon pine | | | | | 6 | 2-10 | 10 | 4-6 | | |
| *Nolina micrantha*--smallseed sacahuista | | | 2 | 0-4 | 7 | 4-10 | | | | |

Data based on transects 185, 186

Aspects: None

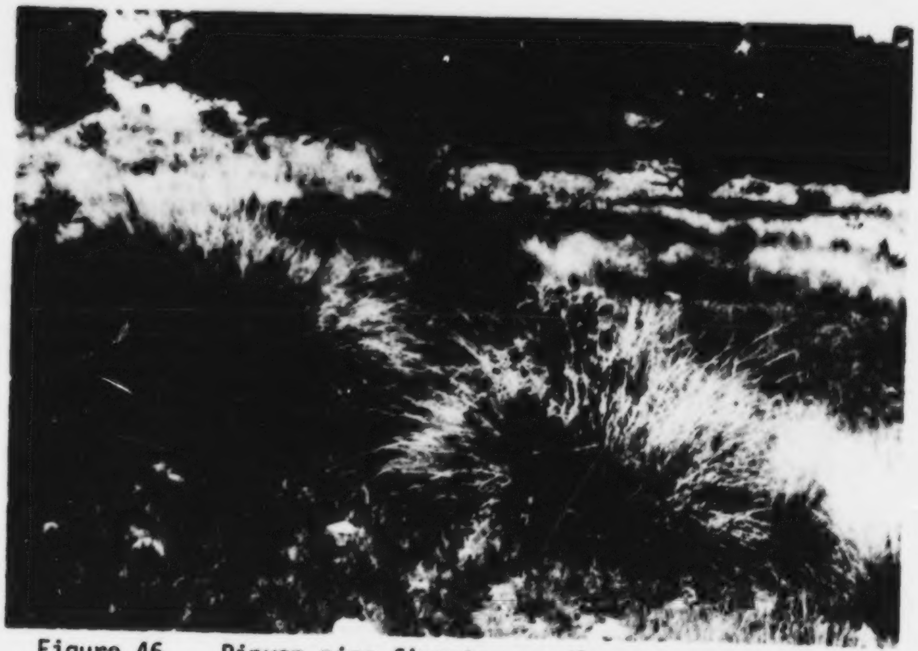

Figure 46. Pinyon pine-finestem needlegrass community.

Figure 47. Valley Floor Site; alligator juniper-gray oak-sideoats grama community. (Meadow in center is the Meadow Site; finestem needlegrass community.)

and desert ceanothus were also present. Finestem needlegrass (Stipa tenuissima) was the dominant grass, making up 48% of the vegetation. Mat muhly (Muhlenbergia repens) (18%) and wolftail (14%) were also common. Blue grama (Bouteloua gracilis) was locally common. In addition, there were small amounts of plains lovegrass, sideoats grama, pine muhly and New Mexico muhly. Only 4% of the vegetation was made up of forbs, which included Cirsium spp. and common horehound (Marrubium vulgare). This vegetation is considered unusual for the area, and is probably the result of livestock disturbance when the area was ranched. A remnant fenceline in the area indicates that this region was a livestock holding area in the past. The presence of finestem needlegrass and mat muhly may be explained if hay was fed to livestock in the area, or if animals distributed the seed in excrement.

Further down this ridge leading into Trail Canyon, there was more small rock (34%) and less litter (38%). Grasses (73%) made up a smaller proportion of the vegetation, with the remainder equally divided among forbs and shrubs. This area had much less overstory (13%), due primarily to the absence of pinyon pine in the samples, although scattered individuals of this species were noted. The smallseed sacahuista-plains lovegrass community (Table 39) occurred in this area. Smallseed sacahuista (5%) was the most common shrub species, and contributed 8% to the overstory. Also found in small amounts were mountain mahogany, algarita, wavyleaf oak and cholla. Plains lovegrass (22%), finestem needlegrass (16%), sideoats grama (13%) and New Mexico muhly (9%) were present, along with smaller amounts of mat muhly and littleawn needlegrass. There were more forbs (14%) in this community than in the pinyon pine-finestem needlegrass community. James nailwort (8%), prickleaf gilia (4%) and fendler euphorbia (Euphorbia fendleri) (4%) were the most common species. This vegetation may represent a transition between the pinyon pine-finestem needlegrass community and the more typical vegetation of the Open Ridgetop site.

Even further down this ridge, small rock ground cover increased to 52%, and there were equal amounts of grasses, forbs and shrubs in the vegetation. Mountain mahogany and wavyleaf oak joined smallseed sacahuista as the most important shrubs, and overstory increased to 30%. Finestem needlegrass was not found here. Plains lovegrass (10%) and

TABLE 39. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-PLAINS LOVEGRASS COMMUNITY (INCLUSION)

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7150 | 7080-7160 | | | | | | | | |
| Slope (%) | 13 | 13 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 16 | 4-28 | | | | | | | | |
| Litter | 38 | 32-44 | | | | | | | | |
| Small rock | 34 | 22-46 | | | | | | | | |
| Large rock | 3 | 0-6 | | | | | | | | |
| Bare ground | 9 | 6-12 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 12 | 10-14 | | | | | | | | |
| 6-20' | 1 | 0-2 | | | | | | | | |
| > 20 | 0 | -- | | | | | | | | |
| Total | 13 | 10-16 | | | | | | | | |
| Grasses (%) | 73 | 64-82 | | | | | | | | |
| Forbs (%) | 14 | 2-26 | | | | | | | | |
| Shrubs (%) | 13 | 10-16 | | | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 22 | | | | | | | |
| *Stipa tenuissima*--finestem needlegrass | | | 16 | | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 13 | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 9 | | | | | | | |
| *Muhlenbergia repens*--mat muhly | | | 5 | | | | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 5 | 4-6 | 8 | 8 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 3 | 2-4 | 3 | 2-4 | | | | |
| *Quercus undulata*--wavyleaf oak | | | 2 | 2 | | | | | | |
| *Opuntia engelmannii*--Engelmann pricklypear | | | 3 | 0-6 | | | | | | |

Data based on transects 24, 187

Aspects: Northern

sideoats grama (8%) were the most common grasses. Thirty-two percent of the vegetation was made up of forbs, the most common of which were baby-white-aster (14%) and James nailwort (10%).

On a steep (48%) protected northwestern aspect in Trail Canyon was an area with site characteristics approximately similar to the Steep Wooded Slope (49%) site (see below) in southern Upper Dog Canyon. However, in this area, there was slightly more small rock (30%), and less large rock (4%) and bare ground (1%). The elevation was also lower, ranging from 6880-7080 ft. Because of these differences, and the different soils between the two areas, this aspect represents a distinct site, but is small enough in extent to warrant only inclusion status.

The ponderosa pine-New Mexico muhly-littleawn needlegrass community (Table 40) was found in this inclusion. Amount of overstory was similar to amount of overstory on the Steep Wooded Slope (49%) site (discussed below). Ponderosa pine was the characteristic species, and Douglas fir (*Pseudotsuga menziesii*) and pinyon pines, found in the Douglas fir-New Mexico muhly community of the Steep Wooded Slope (49%) site, were absent. Also, the ponderosa pine-New Mexico muhly-littleawn needlegrass community had significant amounts of smallseed sacahuista (8% in the species composition and 6% in the overstory); this species was absent from the Douglas fir-New Mexico muhly community and the ponderosa pine-wavyleaf oak-New Mexico muhly community (of the Steep Wooded Slope (49%) site). However, all three communities had considerable quantities of wavyleaf oak. New Mexico muhly (11%) and littleawn needlegrass (11%) were the most common grasses, although there were significant amounts of sideoats grama (9%), *Carex* spp. (9%) and little bluestem (8%). The decreased abundance of New Mexico muhly and the increased abundance of sideoats grama and little bluestem also differentiated this community from the Douglas fir-New Mexico muhly community and the ponderosa pine-wavyleaf oak-New Mexico muhly community. Forbs made up a greater proportion of the vegetation in the ponderosa pine-New Mexico muhly-littleawn needlegrass community (17%). Prairie bluets, prickleaf gilia and James nailwort combined to make up about 12% of the species composition.

## TABLE 40. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PONDEROSA PINE-NEW MEXICO MUHLY-LITTLEAWN NEEDLEGRASS COMMUNITY (INCLUSION)

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7060 | 6880-7080 | | | | | | | | |
| Slope (%) | 48 | 46-50 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 7 | 2-10 | | | | | | | | |
| Litter | 58 | 48-70 | | | | | | | | |
| Small rock | 30 | 18-38 | | | | | | | | |
| Large rock | 4 | 2-8 | | | | | | | | |
| Cryptogam | 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 29 | 24-38 | | | | | | | | |
| 6-20' | 9 | 6-14 | | | | | | | | |
| > 20' | 1 | 0-14 | | | | | | | | |
| Total | 39 | 32-52 | | | | | | | | |
| Grasses (%) | 50 | 46-52 | | | | | | | | |
| Forbs (%) | 17 | 16-18 | | | | | | | | |
| Shrubs (%) | 33 | 30-36 | | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 11 | 2-16 | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 11 | 8-14 | | | | | | |
| *Bouteloua curtipendula*-sideoats grama | | | 9 | 6-12 | | | | | | |
| *Carex* spp.--sedge | | | 9 | 4-12 | | | | | | |
| *Schizachyrium scoparium*--little bluestem | | | 8 | 6-10 | | | | | | |
| *Pinus ponderosa*--ponderosa pine | | | | | 5 | 2-12 | 8 | 4-14 | 1 | 0-4 |
| *Quercus undulata*--wavyleaf oak | | | 24 | 18-28 | 19 | 14-22 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 8 | 4-10 | 6 | 4-8 | | | | |

Data based on transects 26, 188, 189

Aspects: Protected northwestern

## DRY, ROCKY SLOPE (21%)--SITE

On north facing aspects with 21% slope (just west of "New Home Canyon") is an area with site characteristics which did not fit into any of the sites discussed up to this point, having approximately equal proportions of vegetative ground cover, litter, small rock and large rock. This area constituted the Dry, Rocky Slope (21%) site, and supported the smallseed sacahuista-mountain mahogany-pine muhly-plains lovegrass community (Table 41). Considering the codominant overstory species (smallseed sacahuista and mountain mahogany), one of the codominant understory species (plains lovegrass), and several of the subordinant understory species (wolftail, sideoats grama and littleawn needlegrass), this community is related to the smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community of the Open Ridgetop site. However, pine muhly was the most common grass in the smallseed sacahuista-mountain mahogany-pine muhly-plains lovegrass community, but made up only 1% of the species composition of the smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community. Also, New Mexico feathergrass and blue threeawn, both important in the smallseed sacahuista-mountain mahogany-plains lovegrass-New Mexico feathergrass community, were infrequent or absent in the smallseed sacahuista-mountain mahogany-pine muhly-plains lovegrass community. Common forbs in the smallseed sacahuista-mountain mahogany-pine muhly-plains lovegrass community included James nailwort, longstalk greenthread and narrowleaf milkwort (Polygala longa), which combined to account for 10% of the species composition.

Within this area were inclusions with greater slopes. The smallseed sacahuista-sideoats grama community, previously discussed, occurred on the eastern aspects. A variation of the smallseed sacahuista-New Mexico muhly-littleawn needlegrass-sideoats grama community, also previously discussed, occurred on the western aspects.

## VALLEY FLOOR--SITE

Valley floors were very heterogeneous and difficult to characterize. They were often of limited areal extent, largely restricted to the narrow regions between steep slopes. Often, where tree overstory, for example, of alligator juniper (Juniperus deppeana) or gray oak (Quercus grisea), was important, there were distinct and significant changes in the under-

TABLE 41. SITE CHARACTERISTICS OF THE DRY, ROCKY SLOPE (21%) SITE AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-MOUNTAIN MAHOGANY-PINE MUHLY-PLAINS LOVEGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6600 | 6280-6900 | | | | | | | | |
| Slope (%) | 21 | 16-24 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 19 | 16-24 | | | | | | | | |
| Litter | 21 | 12-32 | | | | | | | | |
| Small rock | 22 | 4-34 | | | | | | | | |
| Large rock | 22 | 16-28 | | | | | | | | |
| Bare ground | 16 | 6-28 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 15 | 8-18 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 15 | 8-18 | | | | | | | | |
| Grasses (%) | 71 | 64-88 | | | | | | | | |
| Forbs (%) | 14 | 0-32 | | | | | | | | |
| Shrubs (%) | 15 | 4-28 | | | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 14 | 4-28 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 14 | 4-18 | | | | | | |
| Lycurus phleoides--wolftail | | | 8 | 2-16 | | | | | | |
| Bouteloua curtipendula-sideoats grama | | | 8 | 0-14 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 7 | 0-20 | | | | | | |
| Nolina micrantha--smallseed sacahuista | | | 4 | 0-8 | 7 | 4-8 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 3 | 0-4 | 5 | 0-8 | | | | |
| Rosa stellata--desert rose | | | 5 | 0-12 | 1 | 0-4 | | | | |
| Quercus undulata--wavyleaf oak | | | < 1 | 0-2 | < 1 | 0-2 | | | | |
| Agave neomexicana--New Mexico agave | | | 1 | 0-4 | | | | | | |

Data based on transects 50, 51, 52A, 52B

Aspects: Northern

story. Even minor changes in topography often resulted in dramatic changes in the vegetation. These areas represented the Valley Floor site and were sampled in the northern part of the watershed.

The alligator juniper-gray oak-sideoats grama community represented a typical expression of the Valley Floor site (Table 42, Figure 47). Throughout the site, sideoats grama (19%) was the dominant grass. Alligator juniper was the most abundant and the most frequent tree. Gray oak was also abundant, but was not as frequent as alligator juniper. Where these trees accounted for significant amounts of overstory, finestem needlegrass and pinyon ricegrass (Piptochaetium fimbriatum) were also abundant, the latter species occurring especially under their canopy. Finestem needlegrass appeared to be restricted to the more level topography. Pinyon pine was also important in the community, and there were occasional chinkapin oak (Quercus muhlenbergii) individuals. Wolftail (11%) and blue grama (11%) were important and relatively consistent throughout the community. Plains lovegrass and pine muhly were more common on the gentle slopes of the site. Common shrubs included smallseed sacahuista, mountain mahogany and desert rose, although a variety of species occurred. James nailwort, longstalk greenthread, germander (Teucrium laciniatum) and plains fleabane (Erigeron modestus) were the most common forbs.

## MEADOW--SITE

Meadows within the Valley Floor site near the main channel of Upper Dog Canyon constituted the Meadow site. DeMoss and Indian meadows fall into this site. The site had no small or large rock, and no bare ground. Litter covered 88% of the ground.

The finestem needlegrass community (Table 43, Figure 47) was found on this site. Grasses comprised 82% of the vegetation, with the remainder being made up of forbs. Finestem needlegrass was the most common plant species in the community, making up 60% of the vegetation. Also present were smaller amounts of sideoats grama (9%) and mat muhly (5%). There were also occasional dense stands of blue grama. Narrowleaf globemallow (Sphaeralcea angustifolia) was the most common forb, comprising 16% of the vegetation. Also, occasional desert rose individuals were noted.

TABLE 42. SITE CHARACTERISTICS OF THE VALLEY FLOOR SITE AND SPECIES COMPOSITION OF THE ALLIGATOR JUNIPER-GRAY OAK-SIDEOATS GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6280 | 6200-6600 | | | | | | | | |
| Slope (%) | 10 | 3-19 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 8 | 4-12 | | | | | | | | |
| Litter | 51 | 34-70 | | | | | | | | |
| Small rock | 13 | 0-30 | | | | | | | | |
| Large rock | 12 | 0-36 | | | | | | | | |
| Bare ground | 15 | 4-30 | | | | | | | | |
| Cryptogam | 1 | 0-4 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 16 | 6-24 | | | | | | | | |
| 6-20' | 18 | 0-34 | | | | | | | | |
| > 20' | 1 | 0-2 | | | | | | | | |
| Total | 35 | 10-58 | | | | | | | | |
| Grasses (%) | 80 | 66-90 | | | | | | | | |
| Forbs (%) | 12 | 2-26 | | | | | | | | |
| Shrubs (%) | 8 | 0-18 | | | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 19 | 8-26 | | | | | | |
| *Bouteloua gracilis*--blue grama | | | 11 | 0-34 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 11 | 6-18 | | | | | | |
| *Stipa tenuissima*--finestem needlegrass | | | 9 | 0-36 | | | | | | |
| *Piptochaetium fimbriatum*--pinyon ricegrass | | | 8 | 0-18 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 6 | 0-22 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 6 | 0-22 | | | | | | |
| *Juniperus deppeana*--alligator juniper | | | < 1 | 0-6 | 4 | 0-12 | 9 | 9-14 | < 1 | 0-2 |
| *Quercus grisea*--gray oak | | | < 1 | 0-2 | 4 | 0-14 | 6 | 0-20 | | |
| *Rosa stellata*--desert rose | | | 2 | 0-6 | 1 | 0-8 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 1 | 0-4 | 2 | 0-10 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | < 1 | 0-4 | 2 | 0-6 | | | | |

Data based on transects 202-209

Aspects: None

## TABLE 43. SITE CHARACTERISTICS OF THE MEADOW SITE AND SPECIES COMPOSITION OF THE FINESTEM NEEDLEGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6240 | 6200-6400 | | | | | | | | |
| Slope (%) | 1 | 0-2 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 12 | 12 | | | | | | | | |
| Litter | 88 | 88 | | | | | | | | |
| Small rock | 0 | -- | | | | | | | | |
| Large rock | 0 | -- | | | | | | | | |
| Bare ground | 0 | -- | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 0 | -- | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 0 | -- | | | | | | | | |
| Grasses (%) | 82 | 76-88 | | | | | | | | |
| Forbs (%) | 17 | 12-22 | | | | | | | | |
| Shrubs (%) | 1 | 0-2 | | | | | | | | |
| *Stipa tenuissima*--finestem needlegrass | | | 60 | 60 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 9 | 4-14 | | | | | | |
| *Muhlenbergia repens*--mat muhly | | | 5 | 0-10 | | | | | | |

Data based on transects 200, 201

Aspects: None

ESCARPMENT--SITE

West-facing aspects at 6300-6800 ft. along the eastern escarpment of the watershed, north of the mouth of Bear Canyon, had site characteristics similar to the Heavily Oaken Slope (49%) site. However, this area had much less overstory. Because of the change in aspect, this region was assigned to the Escarpment site (Table 44, Figure 48).

Two major communities occurred in the Escarpment site, distinguished primarily by the abundance of smallseed sacahuista in the overstory. The wavyleaf oak-pine muhly community (Table 45, Figure 49) had only small amounts of smallseed sacahuista, with 3% in the species composition and 2% in the overstory. Gambel oak (Quercus gambelii) was also present in small amounts, making up 3% of the species composition and 1% of the overstory. In one protected northern exposure, there was a relatively dense motte of this species. There were also small amounts of desert ceanothus and skunkbush (Rhus aromatica) in this community. Overstory totaled 29%. Little bluestem (8%) and sideoats grama (7%) were common understory species. There was a variety of forbs, the most common of which were James nailwort, plume brickellbush (Brickellia brachyphylla), Galium spp. and white sage (Artemisia ludoviciana). These species combined to make up 13% of the species composition. In some areas, at the lower elevations, plains lovegrass and New Mexico muhly were locally abundant. Also, more trees, for example gray oak and alligator juniper, occurred. These areas represent a transition into the Valley Floor site.

The wavyleaf oak-smallseed sacahuista-pine muhly-bull muhly community (Table 46, Figure 50) also occurred on the Escarpment site, and differed from the wavyleaf oak-pine muhly community primarily because of the addition of 12% smallseed sacahuista to the overstory and the abundance of bull muhly (19%). However, total overstory was very similar between the two communities. Desert ceanothus, skunkbush and Gambel oak were infrequent or absent in the wavyleaf oak-smallseed sacahuista-pine muhly-bull muhly community. Bull muhly was much more important, and sideoats grama somewhat less important, in this community than in the wavyleaf oak-pine muhly community. Other grasses included plains lovegrass (5%) and big bluestem (Andropogon gerardii) (4%). None of the many forbs were very abundant. The most common species

## TABLE 44. SITE CHARACTERISTICS OF THE ESCARPMENT SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 6660 | 6300-6800 |
| Slope (%) | 53 | 30-79 |
| Ground Cover (%) | | |
| Vegetation | 10 | 6-14 |
| Litter | 46 | 32-58 |
| Small rock | 29 | 20-42 |
| Large rock | 9 | 4-16 |
| Bare ground | 6 | 2-10 |
| Cryptogam | 0 | -- |
| Overstory (%) | | |
| 0-6' | 24 | 20-38 |
| 6-20' | 0 | -- |
| > 20' | 0 | -- |
| Total | 29 | 20-38 |
| Grasses (%) | 58 | 44-70 |
| Forbs (%) | 17 | 2-34 |
| Shrubs (%) | 25 | 12-46 |

Data based on transects 110-112, 115-118, 129-131

Aspects: Western

Figure 48. Escarpment Site.

Figure 49. Wavyleaf oak-pine muhly community (Escarpment Site) (Foreground: Valley Floor Site; alligator juniper-gray oak-sideoats grama community).

TABLE 45. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-PINE MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6700 | 6300-6800 | | | | | | | | |
| Slope (%) | 52 | 30-71 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 10 | 8-14 | | | | | | | | |
| Litter | 44 | 32-56 | | | | | | | | |
| Small rock | 32 | 20-42 | | | | | | | | |
| Large rock | 8 | 6-12 | | | | | | | | |
| Bare ground | 6 | 2-10 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 29 | 20-38 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 29 | 20-38 | | | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 19 | 12-28 | | | | | | |
| Muhlenbergia emersleyi--bull muhly | | | 8 | 0-18 | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 7 | 4-10 | | | | | | |
| Andropogon gerardii-big bluestem | | | 5 | 0-8 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 3 | 0-12 | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 2 | 0-6 | | | | | | |
| Quercus undulata--wavyleaf oak | | | 15 | 4-26 | 21 | 12-38 | | | | |
| Nolina micrantha--smallseed sacahuista | | | 3 | 0-8 | 2 | 0-8 | | | | |
| Quercus gambelli--Gambel oak | | | 3 | 0-8 | 1 | 0-4 | | | | |
| Ceanothus greggii--desert ceanothus | | | < 1 | 0-4 | 2 | 0-10 | | | | |

Data based on transects 110-112, 129-131

Aspects: Western

TABLE 46. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMALLSEED SACAHUISTA-PINE MUHLY-BULL MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6600 | 6300-6800 | | | | | | | | |
| Slope (%) | 54 | 30-79 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 10 | 6-14 | | | | | | | | |
| Litter | 48 | 42-58 | | | | | | | | |
| Small rock | 26 | 20-36 | | | | | | | | |
| Large rock | 10 | 4-16 | | | | | | | | |
| Bare ground | 6 | 4-8 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory | | | | | | | | | | |
| 0-6' | 30 | 26-34 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 30 | 26-34 | | | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 20 | 10-30 | | | | | | |
| *Muhlenbergia emersleyi*--bull muhly | | | 19 | 6-38 | | | | | | |
| *Andropogon gerardii*--big bluestem | | | 6 | 0-12 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 5 | 4-6 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 4 | 0-8 | | | | | | |
| *Quercus undulata*--wavyleaf oak | | | 15 | 10-26 | 17 | 12-20 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 5 | 2-8 | 12 | 8-16 | | | | |

Data based on transects 115-118

Aspects: Western

Figure 50. Background: wavyleaf oak-smallseed sacahuista-pine muhly-bull muhly community (Escarpment site). Foreground: Valley Floor Site: alligator juniper-gray oak-sideoats grama community.

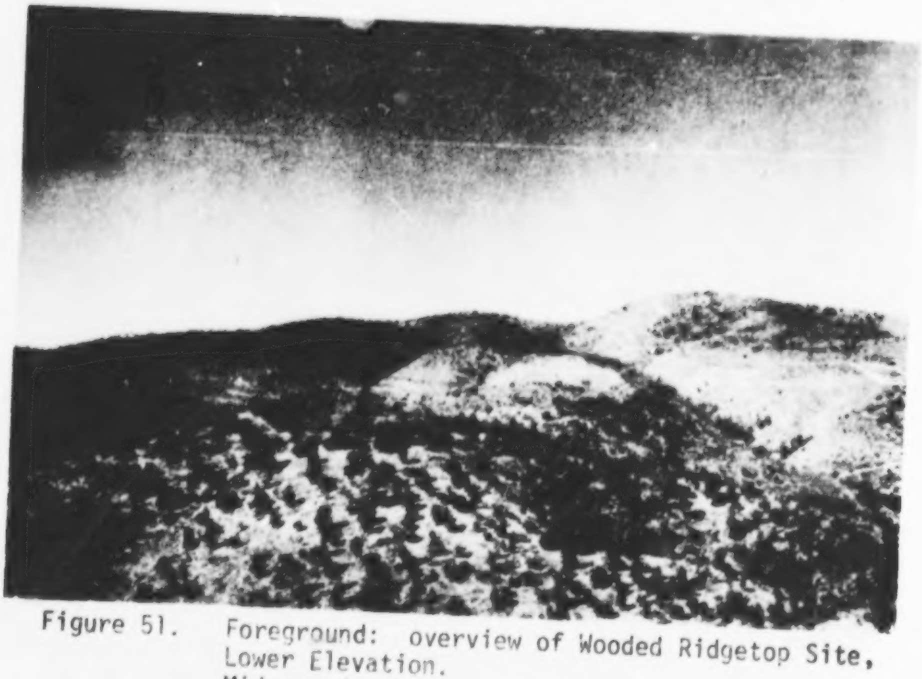

Figure 51. Foreground: overview of Wooded Ridgetop Site, Lower Elevation.
Midground: Dry, Stony Slope (58%) Site.
Background: (center and left) Wooded Ridgetop Site, Higher Elevations. Steeper areas at these higher elevations are in the Steep Wooded Slope (49%) site.

were hedeoma, plains fleabane and James nailwort, which combined to make up 3% of the species composition. Plume brickellbush was infrequent.

Steeper portions of the escarpment (Figure 48) were inaccessible and consequently were not sampled.

## WOODED RIDGETOP--SITE

The Wooded Ridgetop site occurred in middle to southern Upper Dog Canyon over a broad elevational range (6600-7800 ft.) (Table 47, Figure 51). This site occurred on the level ridgetop summits to moderately sloping ridgetops as they assumed a northern aspect and decreased in elevation. Several plant communities occurred on the Wooded Ridgetop site. Often, topographic positions on the ridgetop, and hence localized soil characteristics, supported small inclusions of distinct plant communities. Although the site is characteristically wooded, there are areas relatively free of canopy cover, and amounts of overstory can be misleading. Also, when there were drastic changes in the overstory, understory vegetation usually also changed.

The ponderosa pine-alligator juniper-pine muhly community complex occurred at the lower elevations (6600-7250 ft.) (Table 48) of the site. This community was assigned a complex status because of localized topo-edaphic features which had a profound effect on the vegetation. Wavyleaf oak was an important shrub throughout the complex. There were several distinct communities within the complex.

At the lowest elevations (6940 ft.) on and near the ridgetop summits, areas were somewhat open. Localized reddish sandstone soil outcrops supported a ponderosa pine-alligator juniper-pine muhly-bull muhly community (Figure 52). Ponderosa pine did not occur at any of the transects, although it was noted in the area. Alligator juniper occurred sporadically during sampling, but when it did occur, it made up 10% and 14% of the overstory at the 0-6 and 6-20 ft. levels, respectively. Shrubs included mountain mahogany, desert ceanothus, smallseed sacahuista and small amounts of smooth sotol. Wavyleaf oak made up 13% and 8% of the species composition and overstory, respectively. The abundance of bull muhly (22%) was a characteristic feature of this community; however, in some of the drier areas, it was much less abundant. Pine muhly and bull muhly combined to account for 47% of the vegetation.

## TABLE 47. SITE CHARACTERISTICS OF THE WOODED RIDGETOP SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 7259 | 6600-7800 |
| Slope (%) | 18 | 10-35 |
| Ground Cover (%) | | |
| Vegetation | 16 | 8-28 |
| Litter | 48 | 28-70 |
| Small rock | 20 | 4-45 |
| Large rock | 10 | 0-25 |
| Bare ground | 6 | 0-16 |
| Cryptogam | 0 | -- |
| Overstory (%) | | |
| 0-6' | 18 | 0-38 |
| 6-20' | 6 | 0-18 |
| > 20' | 1 | 0-16 |
| Total | 25 | 0-58 |
| Grasses (%) | 61 | 35-86 |
| Forbs (%) | 15 | 2-35 |
| Shrubs (%) | 24 | 0-40 |

Data based on transects 36, 38, 39, 41-44, 53-59, 80-86, 89, 90, 146-148, 151

Aspects: Northern to none

## TABLE 48. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PONDEROSA PINE-ALLIGATOR JUNIPER-PINE MUHLY COMMUNITY COMPLEX

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6980 | 6600-7250 | | | | | | | | |
| Slope (%) | 21 | 14-35 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 17 | 8-28 | | | | | | | | |
| Litter | 48 | 28-65 | | | | | | | | |
| Small rock | 21 | 8-45 | | | | | | | | |
| Large rock | 9 | 0-25 | | | | | | | | |
| Bare ground | 4 | 0-13 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 13 | 0-26 | | | | | | | | |
| 6-20' | 4 | 0-18 | | | | | | | | |
| > 20' | 2 | 0-16 | | | | | | | | |
| Total | 19 | 0-42 | | | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 23 | 10-36 | | | | | | |
| *Muhlenbergia emersleyi*--bull muhly | | | 7 | 0-40 | | | | | | |
| *Schizachyrium scoparium*--little bluestem | | | 5 | 0-28 | | | | | | |
| *Carex* spp.--sedge | | | 5 | 0-14 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 5 | 0-10 | | | | | | |
| *Muhlenbergia pacifiora*--New Mexico muhly | | | 2 | 0-10 | | | | | | |
| *Pinus ponderosa*--ponderosa pine | | | | | 1 | 0-4 | 2 | 0-16 | 2 | 0-16 |
| *Juniperus deppeana*--alligator juniper | | | 1 | 0-5 | 1 | 0-10 | 2 | 0-14 | | |
| *Quercus undulata*--wavyleaf oak | | | 18 | 0-38 | 6 | 0-16 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 1 | 0-12 | 2 | 0-10 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 2 | 0-8 | < 1 | 0-5 | | | | |

Data based on transects 36, 38, 39, 41-44, 53-59

Aspects: Northern

Figure 52. Ponderosa pine-alligator juniper-pine muhly-bull muhly community within the ponderosa pine-alligator juniper-pine muhly community complex (Wooded Ridgetop Site).

Figure 53. Ponderosa pine-alligator juniper-pine muhly community within the ponderosa pine-alligator juniper-pine muhly community complex (center and right) (Wooded Ridgetop Site).

Pinyon ricegrass , plains lovegrass and sideoats grama each contributed an additional 4%. Only 9% of the vegetation was made up of forbs, and species diversity was low. Plains fleabane, James nailwort and white milkwort (Polygala alba) were the most common forbs, combining to make up 7% of the species composition.

Further northward along the ridgetops at the lowest elevations (6680 ft.) was the ponderosa pine-alligator juniper-pine muhly-little bluestem community. More ponderosa pine and less alligator juniper occurred in the samples, although both species were noted in the area. Mountain mahogany was more abundant, both in species composition and overstory, than in the ponderosa pine-alligator juniper-pine muhly-bull muhly community. There was also less smallseed sacahuista in the species composition, but more in the overstory, than in the ponderosa pine-alligator juniper-pine muhly-bull muhly community. Desert ceanothus and smooth sotol were absent. Wavyleaf oak made up 15% and 6% of the species composition and overstory, respectively. In this community, little bluestem (17%) replaced bull muhly as the second most important understory species, and bull muhly was infrequent or absent. Sideoats grama and Carex spp. each contributed 4-5% to the vegetation, and plains lovegrass and pinyon rice-grass were infrequent or absent. A wider variety of forbs were present in this community than in the ponderosa pine-alligator juniper-pine muhly-bull muhly community, and forbs accounted for much more of the vegetation (20%). James nailwort, longstalk greenthread, needleleaf bluets (Hedyotis acerosa), and plains bluets combined to make up 11% of the species composition. Other forbs included stemmed bitterweed (Hymenoxys scaposa), plume brickellbush, white sage and hedeoma.

The ponderosa pine-alligator juniper-pine muhly community occurred at intermediate elevations (7000-7250 ft.) (Figure 53). Both alligator juniper and ponderosa pine were more common than in the two previous communities of the complex. Wavyleaf oak made up 21% and 6% of the species composition and overstory, respectively. Little bluestem and smallseed sacahuista were infrequent or absent on the ridgetop summits. Sideoats grama, Carex spp., big bluestem and bull muhly were present in small and approximately equal amounts, combining to account for about 13% of the vegetation. Thirty percent of the vegetation was composed of forbs, the most important of which were plains fleabane (15%), white sage (5%), James nailwort (3%) and mountain parsley (Pseudocymopterus montanus) (3%). However, there was not a wide variety of forbs.

Further northward along these ridgetops (7050 ft.), smallseed sacahuista and New Mexico agave were present. Wavyleaf oak made up 22% and 6% of the species composition and overstory, respectively. Carex spp., sideoats grama, little bluestem and New Mexico muhly also occurred in greater amounts. Forbs made up a smaller proportion of the vegetation (16%), although the variety was greater. Galium spp., hedeoma and plains fleabane combined to account for 17% of the species composition.

The wavyleaf oak-mountain mahogany-plains lovegrass-pine muhly community (Table 49) occurred in the drier, less wooded areas of the Wooded Ridgetop site at lower elevations (6600-7105 ft.) (Figure 54). This community occurred in areas with slightly more small rock (29%), and less litter (37%) and overstory (16%), than the typical Wooded Ridgetop site. There was less tree overstory in this community; ponderosa pine did not occur in the samples, and alligator juniper and pinyon pine were infrequent or absent. Wavyleaf oak made up 7% of the species composition and 4% of the overstory and mountain mahogany made up 4% of the species composition and 6% of the overstory. Smallseed sacahuista was also a common shrub. Plains lovegrass (18%) and pine muhly (10%) were the most common grasses. Other common species included Carex spp. (8%), New Mexico muhly (8%), blue threeawn (6%) and sideoats grama (5%). There was a wide variety of forbs. Allium spp., white milkwort, stemmed bitterweed, snowy flameflower (Talinum pulchellum), plains blackfoot, James nailwort and hedeoma combined to make up 10% of the species composition.

At the highest elevations of the Wooded Ridgetop site (7300-7800 ft.), primarily on the ridgetops connected to and extending northward from McKittrick Ridge, there was the pinyon pine-New Mexico muhly community (Table 50, Figure 55). Pinyon pine was the most common tree species (especially at the higher elevations), making up 9% of the overstory at the 0-6 ft. level and 5% at the 6-20 ft. level. Ponderosa pine and alligator juniper also occurred in the overstory. Wavyleaf oak was the most common shrub, accounting for 8% of the species compo-

TABLE 49. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-MOUNTAIN MAHOGANY-PLAINS LOVEGRASS-PINE MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6968 | 6600-7150 | | | | | | | | |
| Slope (%) | 29 | 12-40 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 15 | 6-24 | | | | | | | | |
| Litter | 37 | 28-54 | | | | | | | | |
| Small rock | 29 | 25-36 | | | | | | | | |
| Large rock | 10 | 5-22 | | | | | | | | |
| Bare ground | 9 | 1-16 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 16 | 10-20 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 16 | 10-20 | | | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 18 | 13-24 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 10 | 6-14 | | | | | | |
| *Carex* spp.--sedge | | | 8 | 2-13 | | | | | | |
| *Aristida glauca*--blue threeawn | | | 6 | 0-8 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 5 | 2-6 | | | | | | |
| *Quercus undulata*--wavyleaf oak | | | 7 | 2-17 | 4 | 0-8 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 4 | 0-8 | 6 | 3-8 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 4 | 2-5 | 3 | 0-6 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | < 1 | 0-2 | 2 | 0-5 | | | | |

Data based on transects 33, 45, 60, 61

Aspects: Northern to northwestern

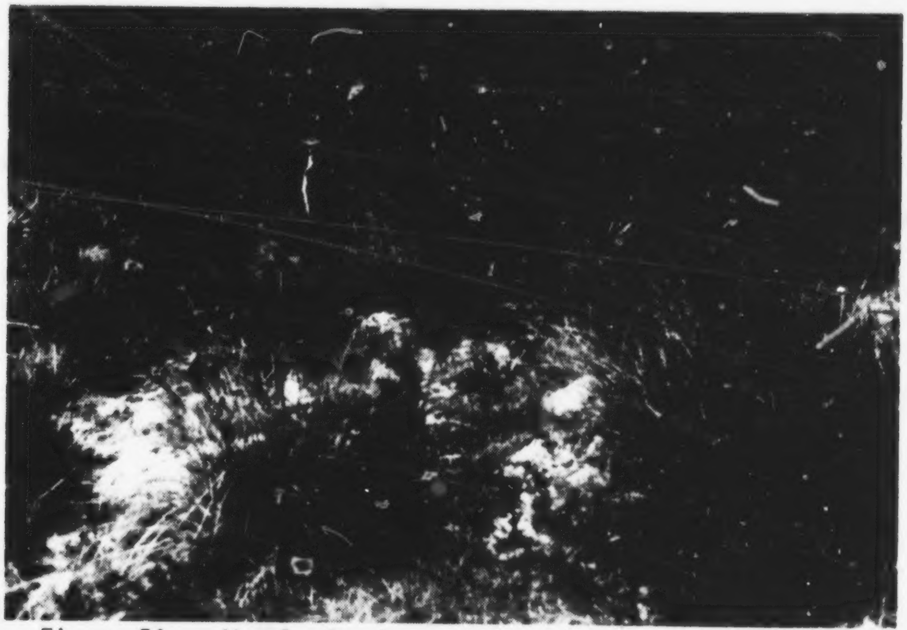

Figure 54. Wavyleaf oak-mountain mahogany-plains lovegrass-pine muhly community (Wooded Ridgetop Site).

Figure 55. Pinyon pine-New Mexico muhly community (Wooded Ridgetop Site).

TABLE 50. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PINYON PINE-NEW MEXICO MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7600 | 7300-7800 | | | | | | | | |
| Slope (%) | 14 | 10-21 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 14 | 8-24 | | | | | | | | |
| Litter | 50 | 36-70 | | | | | | | | |
| Small rock | 19 | 4-36 | | | | | | | | |
| Large rock | 10 | 0-18 | | | | | | | | |
| Bare ground | 7 | 0-18 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 18 | 0-38 | | | | | | | | |
| 6-20' | 6 | 0-18 | | | | | | | | |
| > 20' | 1 | 0-4 | | | | | | | | |
| Total | 25 | 12-56 | | | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 31 | 8-56 | | | | | | |
| Carex spp.--sedge | | | 10 | 2-16 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 7 | 4-12 | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 5 | 0-10 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 4 | 0-14 | | | | | | |
| Schizachyrium scoparium--little bluestem | | | 3 | 0-8 | | | | | | |
| Pinus edulis--pinyon pine | | | 1 | 0-4 | 9 | 0-24 | 5 | 0-12 | | |
| Quercus undulata--wavyleaf oak | | | 8 | 4-10 | 9 | 0-24 | | | | |
| Juniperus deppeana--alligator juniper | | | | | < 1 | 0-4 | 1 | 0-4 | | |
| Pinus ponderosa--ponderosa pine | | | | | | | 2 | 0-8 | 1 | 0-4 |
| Agave neomexicana--New Mexico agave | | | 3 | 0-8 | | | | | | |
| Nolina micrantha--smallseed sacahuista | | | 4 | 0-10 | 2 | 0-4 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 2 | 0-6 | 3 | 0-10 | | | | |
| Ceanothus greggii--desert ceanothus | | | < 1 | 0-4 | < 1 | 0-2 | | | | |

Data based on transects 80-86, 146-148

Aspects: Northeastern

sition and 9% of the overstory. Smallseed sacahuista and mountain mahogany were also present. In general, there was less wavyleaf oak in the species composition than in the ponderosa pine-alligator juniper-pine muhly community complex, although its abundance in the overstory was similar. New Mexico muhly (31%) and Carex spp. (10%) were the most common grasses. Littleawn needlegrass (7%), sideoats grama (5%), plains lovegrass (4%) and little bluestem (3%) also occurred, along with about 3% each of pine muhly and pinyon ricegrass. However, pine muhly was important in areas with less tree overstory. Forbs accounted for only 10% of the vegetation. James nailwort, longstalk greenthread and Allium spp. were the most common forbs, and accounted for 9% of the vegetation.

Further northward along these ridgetops at lower elevations, conditions generally became somewhat more xeric. Tree density also decreased and many areas were free of overstory. The ponderosa pine-wavyleaf oak-Carex community was found in these areas (Table 51). There was much less New Mexico muhly (1%) in this community than in the pinyon pine-New Mexico muhly community. Although Carex spp. was a dominant understory species, its abundance (13%) was similar in this community and in the pinyon pine-New Mexico muhly community. Other important grasses included littleawn needlegrass (10%) and sideoats grama (9%), with smaller amounts of pinyon ricegrass (6%), little bluestem (6%) and plains lovegrass (5%). Smallseed sacahuista was more common, both in the species composition and overstory, and there were small amounts of smooth sotol. However, amounts of wavyleaf oak were similar in this community and in the pinyon pine-New Mexico muhly community. Sixteen percent of the vegetation was made up of forbs, the most common of which were James nailwort (8%), longstalk greenthread (3%) and noseburn (1%). Thus, this community is an expression of the drier conditions in these areas of the higher elevation ridgetops.

## STEEP WOODED SLOPE (49%)--SITE

The Steep Wooded Slope (49%) site was found on northeastern to northwestern aspects at 6400-7700 ft. in south Upper Dog Canyon, primarily along the ridges which extended northward from McKittrick Ridge (Table 52). This site had less vegetative ground cover and bare

TABLE 51. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PONDEROSA PINE-WAVYLEAF OAK-CAREX COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7400 | 7200-7700 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 17 | 8-22 | | | | | | | | |
| Litter | 43 | 42-46 | | | | | | | | |
| Small rock | 21 | 20-24 | | | | | | | | |
| Large rock | 11 | 2-18 | | | | | | | | |
| Bare ground | 8 | 2-12 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 21 | 14-30 | | | | | | | | |
| 6-20' | 7 | 0-14 | | | | | | | | |
| > 20' | 1 | 0-4 | | | | | | | | |
| Total | 29 | 26-32 | | | | | | | | |
| Carex spp.--sedge | | | 13 | 12-16 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 10 | 6-12 | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 9 | 0-14 | | | | | | |
| Piptochaetium fimbriatum--pinyon ricegrass | | | 6 | 4-8 | | | | | | |
| Schizachyrium scoparium--little bluestem | | | 6 | 4-8 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 5 | 0-8 | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 4 | 2-6 | | | | | | |
| Pinus ponderosa--ponderosa pine | | | | | 1 | 0-2 | 9 | 0-14 | 1 | 0-4 |
| Quercus undulata--wavyleaf oak | | | 9 | 4-12 | 5 | 4-6 | | | | |
| Nolina micrantha--smallseed sacahuista | | | 7 | 2-24 | 8 | 4-14 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 3 | 2-4 | 4 | 2-6 | | | | |
| Ceanothus greggii-desert ceanothus | | | 1 | 0-2 | 2 | 0-4 | | | | |
| Dasylirion leiophyllum--smooth sotol | | | 2 | 0-6 | < 1 | 0-2 | | | | |

Data based on transects 89, 90, 151

Aspects: None

TABLE 52. SITE CHARACTERISTICS OF THE STEEP WOODED SLOPE (49%) SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 7200 | 6600-7800 |
| Slope (%) | 49 | 27-69 |
| Ground cover (%) | | |
| Vegetation | 10 | 4-18 |
| Litter | 51 | 28-66 |
| Small rock | 21 | 8-38 |
| Large rock | 13 | 4-24 |
| Bare ground | 5 | 0-14 |
| Cryptogam | 0 | -- |
| Overstory (%) | | |
| 0-6' | 26 | 12-50 |
| 6-20' | 9 | 0-28 |
| > 20' | 3 | 0-14 |
| Total | 37 | 22-58 |
| Grasses (%) | 61 | 44-80 |
| Forbs (%) | 9 | 2-18 |
| Shrubs (%) | 30 | 16-48 |

Data based on transects 63, 69-71, 77-79, 119-124, 149, 150

Aspects: Northwestern, northern, northeastern ground, and more slope, large rock and overstory (at all levels) than the Wooded Ridgetop site.

The Douglas fir-New Mexico muhly community was found on heavily wooded northwestern to southwestern aspects (Table 53, Figure 56). Pinyon pine was also very important in this community. There were smaller amounts of ponderosa pine, Knowlton hop-hornbeam (Ostrya knowltonii) and Gambel oak. Big-tooth maple (Acer grandidentatum) was also present, especially on the lower elevations of the ridges. Shrubs made up 24% of the vegetation, and there were several important species in the community. Wavyleaf oak and Utah serviceberry (Amelanchier utahensis) were the most common species, making up 11% and 12%, and 5% and 1% of the species composition and overstory, respectively. There were smaller amounts of cliff fendlerbush (Fendlera rupicola), herba de pasmo (Baccharis pteronioides) and Quercus spp. Forbs made up only 7% of the vegetation. Common species included Galium spp., Allium spp., creeping barberry (Berberis repens) and drummond hedeoma (Hedeoma drummondii). Although grasses made up 68% of the vegetation, there were few species. New Mexico muhly was the most common, comprising 48% of the species composition. Carex spp. (19%) and littleawn needlegrass (7%) were also common.

On steep northern to northeastern aspects at 6600-7200 ft., the ponderosa pine-wavyleaf oak-New Mexico muhly community occurred (Table 54, Figure 57). Because of steep slopes and rough topography in many areas, this community was difficult to characterize. Ponderosa pine dominated the overstory, although wavyleaf oak was also very important. Often, tree overstory in this community was less than in the Douglas fir-New Mexico muhly community. Ponderosa pine did not occur in some of the samples, although it was noted in these areas. Small amounts of Douglas fir, Texas madrone (Arbutus xalapensis), chinkapin oak and Gambel oak were also noted in the community. Utah serviceberry, tatalencho (Gymnosperma glutinosum) and skunkbush were frequent. New Mexico muhly (33%) dominated the understory. Pine muhly accounted for only 9% of the species composition, and Carex spp. and littleawn needlegrass each contributed about 3%. There were only 10% forbs in the vegetation. Hedeoma, white sage and prairie bluets were common species.

TABLE 53. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE DOUGLAS FIR-NEW MEXICO MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7480 | 7000-7800 | | | | | | | | |
| Slope (%) | 49 | 35-72 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 9 | 4-14 | | | | | | | | |
| Litter | 54 | 42-66 | | | | | | | | |
| Small rock | 21 | 10-34 | | | | | | | | |
| Large rock | 14 | 8-24 | | | | | | | | |
| Bare ground | 3 | 0-6 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 23 | 12-38 | | | | | | | | |
| 6-20' | 9 | 0-20 | | | | | | | | |
| > 20' | 3 | 0-14 | | | | | | | | |
| Total | 35 | 22-54 | | | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 48 | 36-58 | | | | | | |
| Carex spp.--sedge | | | 12 | 6-20 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 7 | 2-14 | | | | | | |
| Pseudotsuga menziesii--Douglas fir | | | < 1 | 0-2 | 3 | 0-16 | 2 | 0-8 | 1 | 0-8 |
| Pinus edulis--pinyon pine | | | < 1 | 0-2 | 4 | 0-8 | 3 | 0-8 | | |
| Quercus undulata--wavyleaf oak | | | 11 | 2-18 | 12 | 4-18 | | | | |
| Amelanchier utahensis--Utah serviceberry | | | 5 | 0-10 | < 1 | 0-2 | < 1 | 0-2 | | |
| Fendlera rupicola--cliff fendlerbush | | | 2 | 0-4 | < 1 | 0-2 | | | | |
| Baccharis pteronioides--herba de pasmo | | | 2 | 0-6 | < 1 | 0-2 | | | | |

Data based on transects 119-124, 149, 150

Aspects: Northwestern, northern, southwestern

Figure 56. Steep Wooded Slope (49%) Site; Douglas fir-New Mexico muhly community.

Figure 57. Foreground: Ponderosa pine-wavyleaf oak-New Mexico muhly community (Steep Wooded Slope (49%) site).

TABLE 54. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE PONDEROSA PINE-WAVYLEAF OAK-NEW MEXICO MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6880 | 6600-7200 | | | | | | | | |
| Slope (%) | 48 | 27-69 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 12 | 8-18 | | | | | | | | |
| Litter | 50 | 28-66 | | | | | | | | |
| Small rock | 21 | 8-38 | | | | | | | | |
| Large rock | 11 | 4-16 | | | | | | | | |
| Bare ground | 6 | 0-14 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 29 | 20-50 | | | | | | | | |
| 6-20' | 8 | 0-26 | | | | | | | | |
| > 20' | 2 | 0-14 | | | | | | | | |
| Total | 39 | 26-60 | | | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 33 | 12-58 | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 9 | 0-22 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 3 | 0-10 | | | | | | |
| Carex spp.--sedge | | | 3 | 0-6 | | | | | | |
| Pinus ponderosa--ponderosa pine | | | | | < 1 | 0-2 | 3 | 0-22 | 2 | 0-14 |
| Quercus undulata--wavyleaf oak | | | 18 | 6-34 | 20 | 8-40 | | | | |
| Pinus edulis--pinyon pine | | | | | 2 | 0-10 | 2 | 0-10 | < 1 | 0-2 |
| Gymnosperma glutinosum--tatalencho | | | 4 | 0-10 | 1 | 0-6 | | | | |
| Amelanchier utahensis--Utah serviceberry | | | 7 | 0-18 | < 1 | 0-2 | | | | |

Data based on transects 63, 69-71, 77-79

Aspects: North to northeastern

This community was very similar to the Douglas fir-New Mexico muhly community found on the wooded northwestern aspects, with regard to site characteristics and soils. Also, the dominant shrubs and grasses of the two communities were similar. However, dominant overstory species differed between the two communities.

### STEEP INTERMEDIATELY WOODED SLOPE (50%)--SITE

Moderately steep (33%) to steep (58%) eastern, western, northeastern and northwestern aspects at 6400-7250 ft. in middle Upper Dog Canyon made up the Steep Intermediately Wooded Slope (50%) site. Although the average slope of this site (50%) was very similar to the average slope of the Steep Wooded Slope (49%) site, the Steep Intermediately Wooded Slope (50%) site had less overstory (18%) at all levels, less litter (35%), and more bare ground (7%) and vegetative ground cover (13%).

The alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community was the typical community on this site (Table 55, Figure 58). Throughout the community, alligator juniper occurred fairly consistently in the samples, although it was never abundant. Pinyon pine and ponderosa pine were also present, but were not as frequent in the samples as alligator juniper. New Mexico muhly (24%) and pine muhly (16%) were the most common grasses, with smaller amounts of a variety of species, including bull muhly, Carex spp., plains lovegrass and littleawn needlegrass. There was a variety of forbs which made up 10% of the vegetation. Shrubs and grasses made up 30% and 56%, respectively, of the species composition.

There were several variations of this community. At the lower elevations (6680 ft.) on eastern to western and northeastern to northwestern aspects were areas with less slope (46%) and less overstory (13%) at all levels. Wavyleaf oak made up 13% of the species composition, but only 4% of the overstory. Mountain mahogany, desert ceanothus, New Mexico agave, Utah serviceberry, desert rose, pinyon pine and Utah fendlerella (Fendlerella utahensis) were also present in small amounts. New Mexico muhly and pine muhly made up 21% and 16% of the vegetation, respectively. Sideoats grama (4%), Carex spp. (3%) and blue threeawn (1%) were also present in the understory. Hedeoma (3%), white sage (3%) and James nailwort (2%) were the most common forbs.

TABLE 55. SITE CHARACTERISTICS OF THE STEEP INTERMEDIATELY WOODED SLOPE (50%) SITE AND SPECIES COMPOSITION OF THE ALLIGATOR JUNIPER-WAVYLEAF OAK-NEW MEXICO MUHLY-PINE MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6780 | 6400-7250 | | | | | | | | |
| Slope (%) | 50 | 33-58 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 13 | 6-18 | | | | | | | | |
| Litter | 35 | 22-54 | | | | | | | | |
| Small rock | 28 | 2-42 | | | | | | | | |
| Large rock | 17 | 6-28 | | | | | | | | |
| Bare ground | 7 | 2-16 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 17 | 6-34 | | | | | | | | |
| 6-20' | 1 | 0-6 | | | | | | | | |
| > 20' | 1 | 0-2 | | | | | | | | |
| Total | 18 | 4-38 | | | | | | | | |
| Grasses (%) | 58 | 30-76 | | | | | | | | |
| Forbs (%) | 10 | 5-26 | | | | | | | | |
| Shrubs (%) | 32 | 14-50 | | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 24 | 8-44 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 16 | 4-32 | | | | | | |
| *Muhlenbergia emersleyi*--bull muhly | | | 4 | 0-12 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 3 | 0-14 | | | | | | |
| *Carex* spp.--sedge | | | 2 | 0-16 | | | | | | |
| *Juniperus deppeana*--alligator juniper | | | | | 1 | 0-6 | < 1 | 0-6 | | |
| *Quercus undulata*--wavyleaf oak | | | 14 | 2-32 | 10 | 0-26 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 4 | 0-8 | 2 | 0-8 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 2 | 0-4 | 1 | 0-6 | | | | |
| *Gymnosperma glutinosum*--tatalencho | | | 2 | 0-8 | < 1 | 0-2 | | | | |
| *Baccharis petronioides*--herba de pasmo | | | 2 | 0-4 | < 1 | 0-2 | | | | |

Data based on transects 31, 32, 34, 35, 37, 40, 46, 62, 65-68, 72, 73, 75, 76

Aspects: Western, northeastern, northwestern, eastern

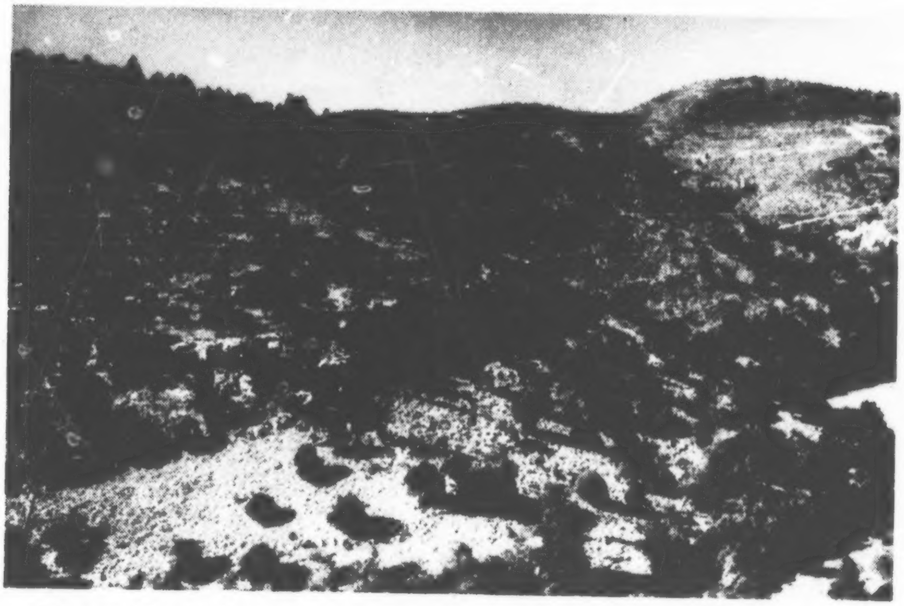

Figure 58. Steep Intermediately Wooded Slope (50%) Site; alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community.

Figure 59. Steep Intermediately Wooded Slope (50%) Site; (Western Aspect); variation of alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community.

On the higher elevations (6840 ft.) western aspects with steeper slopes (56%), there was only 7% wavyleaf oak in the species composition, but 11% in the overstory and total overstory increased to 19% (Figure 59). There was less mountain mahogany, and desert ceanothus, pinyon pine, New Mexico agave, Utah serviceberry and desert rose were infrequent or absent. However, there were small amounts of cliff fendlerbush, Utah fendlerella and silktassel. Blue threeawn and sideoats grama were absent, and bull muhly made up 7% of the vegetation. There was 38% New Mexico muhly and 11% pine muhly. Prairie bluets (8%), Allium spp. (2%) and hedeoma, white sage and schied flax (Linum schiedianum), each at 2%, were the most common forbs.

Also at higher elevations (6900 ft.) and steeper slopes (57%), but on eastern to northeastern aspects, there was more wavyleaf oak, both in species composition (22%) and overstory (20%) (Figure 60). Total overstory increased to 30%. Desert rose, Utah fendlerella, silktassel, Utah serviceberry, cliff fendlerbush and desert ceanothus were infrequent or absent. There were small amounts of pinyon pine, and ponderosa pine was absent from the samples, although it was noted in the area. There was relatively less New Mexico muhly (16%), but more pine muhly (23%). Bull muhly made up 6% of the vegetation. Blue threeawn and sideoats grama were infrequent or absent. The most common forbs were hedeoma (2%), schied flax (2%), and white milkwort, prairie bluets and Cirsium spp., each at 1%.

## STEEP WOODED NORTHEASTERN SLOPE (41%)--SITE

On northeastern aspects at 7200-7900 ft. in the Bear Canyon area in Upper Dog Canyon, slopes averaged 41%. There were large amounts of overstory at all levels, totaling 60%. There was little vegetation ground cover (4%), with 76% litter and 11% large rock. Seventy-five percent of the vegetation was composed of grasses, with the remainder approximately equally divided among forbs and shrubs. These areas comprised the Steep Wooded Northeastern Slope (41%) site.

The ponderosa pine Quercus-New Mexico muhly community (Table 56) was found on this site. Ponderosa pine was the dominant overstory species, accounting for 25% overstory at the 6-20 ft. level and 13% at the greater than 20 ft. level. Wavyleaf oak, Gambel oak and Quercus spp. were common shrubs, combining to make 9% of the species composi-

Figure 60. Steep Intermediately Wooded Slope (50%) Site; (Eastern Aspect); variation of alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community.

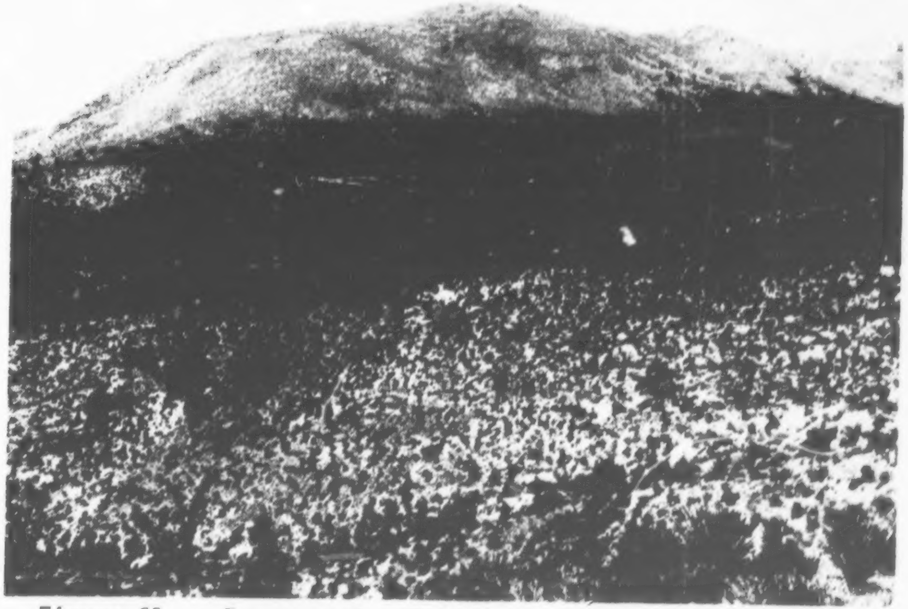

Figure 61. Foreground: PX Ridge Site (Western Aspect); javelina bush-curlyleaf muhly community.
Middleground: PX Flat Site; oneseeded juniper-blue grama community.
Background: PX Ridge Site (Eastern Aspect); smallseed sacahuista-curlyleaf muhly-New Mexico feathergrass community.

TABLE 56. SITE CHARACTERISTICS OF THE STEEP WOODED NORTHEASTERN SLOPE (41%) SITE AND SPECIES COMPOSITION OF THE PONDEROSA PINE-QUERCUS-NEW MEXICO MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7820 | 7200-7900 | | | | | | | | |
| Slope (%) | 41 | 39-44 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 4 | -- | | | | | | | | |
| Litter | 76 | 74-78 | | | | | | | | |
| Small rock | 6 | 2-8 | | | | | | | | |
| Large rock | 11 | 8-12 | | | | | | | | |
| Bare ground | 3 | 2-4 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 22 | 12-34 | | | | | | | | |
| 6-20' | 25 | 24-30 | | | | | | | | |
| > 20' | 13 | 6-18 | | | | | | | | |
| Total | 60 | 52-72 | | | | | | | | |
| Grasses (%) | 75 | 72-78 | | | | | | | | |
| Forbs (%) | 11 | 8-16 | | | | | | | | |
| Shrubs (%) | 14 | 12-16 | | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 61 | 56-68 | | | | | | |
| *Carex* spp.--sedge | | | 6 | 4-10 | | | | | | |
| *Pinus ponderosa*--ponderosa pine | | | | | < 1 | 0-2 | 24 | 20-38 | 13 | 6-18 |
| *Quercus undulata*--wavyleaf oak | | | 5 | 0-10 | 5 | 0-12 | | | | |
| *Quercus* spp.--oak | | | 3 | 0-8 | 7 | 0-12 | | | | |
| *Quercus gambelii*--Gambel oak | | | 1 | 0-4 | 7 | 0-20 | | | | |
| *Gymnosperma glutinosum*--tatalencho | | | 3 | 0-8 | < 1 | 0-2 | | | | |

Data based on transects 210, 211, 212

Aspects: Northeastern

tion and 18% of the overstory at the 0-6 ft. level. Tatalencho was also present. New Mexico muhly was the dominant understory species, accounting for 61% of the vegetation. The only other grass present in significant amounts was Carex spp. (6%). Eleven percent of the vegetation was made up of forbs, the most common of which was creeping barberry (7%) and Galium spp. (3%).

DENSELY WOODED RIDGETOP--SITE

On the densely wooded top of the eastern boundary of Bear Canyon was an area similar to the northeastern ridges. However, there was much more small rock (19%), with slightly less bare ground (3%). Also, slopes were moderate (32%). Total overstory (66%) was similar between the two areas. This area, however, supported very different vegetation, and constituted the Densely Wooded Ridgetop site.

The southwestern white pine-alligator juniper-pringle needlegrass community was found on the Densely Wooded Ridgetop site (Table 57). Southwestern white pine (Pinus strobiformis) dominated the overstory, contributing 23% at the 6-20 ft. level and 9% at the greater than 20 ft. level. Alligator juniper was also very important, accounting for 13% of the 6-20 ft. level. Smaller amounts of ponderosa pine occurred. Wavyleaf oak, Gambel oak and Quercus spp. were also important in the community, contributing 9% to the species composition and 11% to the overstory. Pringle needlegrass (Stipa pringlei) (25%) was the most common understory species. Also common were pine muhly (9%), littleawn needlegrass (8%) and big bluestem (7%), with lesser amounts of Carex spp. (4%), little bluestem (4%) and pine dropseed (Blepharoneuron tricholepsis) (2%). There were a wide variety of forbs making up 23% of the vegetation. The most common species was plains fleabane (13%). Biennial woolywhite (Hymenopappus biennis), Allium spp. and hedeoma occurred in smaller quantities.

## WATERSHED 10A6

Watershed 10A6 extends over a broad elevational range (3705-7680 ft.). Sampling was completed in the upper and lower regions of the watershed. The intermediate area is very rough and inaccessible, and consequently was not sampled. Six sites, twelve communities and one

TABLE 57. SITE CHARACTERISTICS OF THE DENSELY WOODED RIDGETOP SITE AND SPECIES COMPOSITION OF THE SOUTHWESTERN WHITE PINE-ALLIGATOR JUNIPER-PRINGLE NEEDLEGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7880 | 7200-7900 | | | | | | | | |
| Slope (%) | 31 | 29-35 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 3 | 2-4 | | | | | | | | |
| Litter | 68 | 64-72 | | | | | | | | |
| Small rock | 19 | 16-22 | | | | | | | | |
| Large rock | 9 | 8-16 | | | | | | | | |
| Bare ground | 1 | 0-2 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 14 | 6-24 | | | | | | | | |
| 6-20' | 41 | 22-54 | | | | | | | | |
| > 20' | 11 | 6-14 | | | | | | | | |
| Total | 66 | 52-80 | | | | | | | | |
| Grasses (%) | 66 | 54-76 | | | | | | | | |
| Forbs (%) | 23 | 14-28 | | | | | | | | |
| Shrubs (%) | 11 | 4-18 | | | | | | | | |
| Stipa pringlei--Pringle needlegrass | | | 25 | 12-44 | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 9 | 4-12 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 8 | 0-18 | | | | | | |
| Andropogon gerardi--big bluestem | | | 7 | 0-16 | | | | | | |
| Pinus strobiformis--southwestern white pine | | | | | | | 23 | 8-40 | 9 | 2-14 |
| Juniperus deppeana--alligator juniper | | | | | 1 | 0-2 | 13 | 6-24 | | |
| Quercus undulata--wavyleaf oak | | | 4 | 0-12 | 3 | 0-8 | | | | |
| Quercus gambelii--Gambel oak | | | 3 | 0-6 | 4 | 0-10 | 1 | 0-4 | | |
| Quercus spp.--oak | | | 3 | 0-4 | 3 | 0-8 | | | | |
| Pinus ponderosa--ponderosa pine | | | | | < 1 | 0-2 | 3 | 0-8 | 1 | 0-4 |

Data based on transects 213, 214, 215

Aspects: None to western

community complex were delineated in this watershed (Tables 58, 59; Figure 62).

PX RIDGE--SITE

Two sites were found in the upper end of the watershed (Figure 61). The ridges bounding PX Flat on the eastern, western and southern sides made up the PX Ridge site (Table 60). Although similar in appearance to the Dry, Very Stony Slope (50%) site of Watershed 1, this region constituted a different site. There was much less small rock (30%) and overstory (12%), and much more large rock (20%). These differences, together with different soils, aspects and vegetation, warrant a separate site designation.

On western aspects at 6500-7400 ft., the javelina bush-curlyleaf muhly community was found (Table 61, Figure 63). Other common shrubs included smooth sotol, New Mexico agave and mountain mahogany, with smaller amounts of smallseed sacahuista and skeleton goldeneye (Viguiera stenoloba). Grasses comprised 81% of the vegetation. Curlyleaf muhly (33%) was the most common species. Other grasses included New Mexico muhly (11%), plains lovegrass (10%) and littleawn needlegrass (9%). The variety of forbs commonly included Harvard wildbuckwheat (Eriogonum havardii) and rock flax (Linum rupestre).

Along the small channels traversing this aspect, changes in topography supported sometimes dense stands of pinyon pine (Figure 64). Smooth sotol was more common, and javelina bush (Condalia ericoides) less common, in these areas. Littleawn needlegrass (15%) and sideoats grama (6%) were more common, and blue threeawn (3%) less common. Also, fewer forbs were found. In addition, pinyon pine grew more abundantly on the top of this ridge than on the western aspect.

On eastern aspects of the site, the smallseed sacahuista-curlyleaf muhly-New Mexico feathergrass community occurred (Table 62, Figure 65). Javelina bush was absent from this community, and total overstory (5%) was less. Smallseed sacahuista was the only important shrub. Pinyon pine did not occur. The abundance of curlyleaf muhly (31%) was very similar in this community and in the javelina bush-curlyleaf muhly community. However, New Mexico feathergrass (21%) was very important in the smallseed sacahuista-curlyleaf muhly-New Mexico feathergrass

## TABLE 58. SITES AND COMMUNITIES OF WATERSHED 10A6

| Site | Community | Map Symbol |
|---|---|---|
| PX Ridge | Javelina bush-curlyleaf muhly | 17A |
| | Smallseed sacahuista-curlyleaf muhly-New Mexico feathergrass | 17B |
| | *Quercus*-*Carex*-New Mexico muhly | 17C |
| | Mountain mahogany-New Mexico muhly-New Mexico feathergrass | |
| PX Flat | Oneseeded juniper-blue grama | 18A |
| | Mat muhly-blue grama | 19A |
| Creosote | Creosotebush-*Sporobolus*-black grama | 20A |
| | Range ratany-skeleton goldeneye-fluffgrass | 20B |
| Outcrop | Skeleton goldeneye-gray coldenia-slim tridens | 21A |
| | Skeleton goldeneye-smooth sotol-Warnock grama-slim tridens | 21B |
| (Inclusion) | Creosotebush-pepperweed-*Cryptantha* | 22A |
| Gypsum | Range ratany-creosotebush-*Dyssodia*-wooly Indian wheat complex | 23A |
| Channel | Creosotebush-black grama | 24A |
| | (Not sampled) | 25A |

## TABLE 59. VEGETATIVE COMPOSITION WATERSHED 10A6

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| 23A | 15.0 | 373 | .58 |
| 20A | 5.1 | 127 | .20 |
| 20B | 3.5 | 87 | .13 |
| 22A | 0.2 | 5 | .01 |
| 21B | 1.0 | 25 | .04 |
| 21A | 1.9 | 47 | .07 |
| 24A | 3.2 | 80 | .12 |
| 25A | 41.4 | 1,031 | 1.61 |
| 17C | 1.2 | 30 | .05 |
| 17D | 4.8 | 120 | .19 |
| 17A | 10.7 | 266 | .42 |
| 17B | 4.3 | 107 | .17 |
| 18A | 7.1 | 177 | .28 |
| 19A | 0.6 | 15 | .02 |
|  | 100.0 | 2,490 | 3.89 |

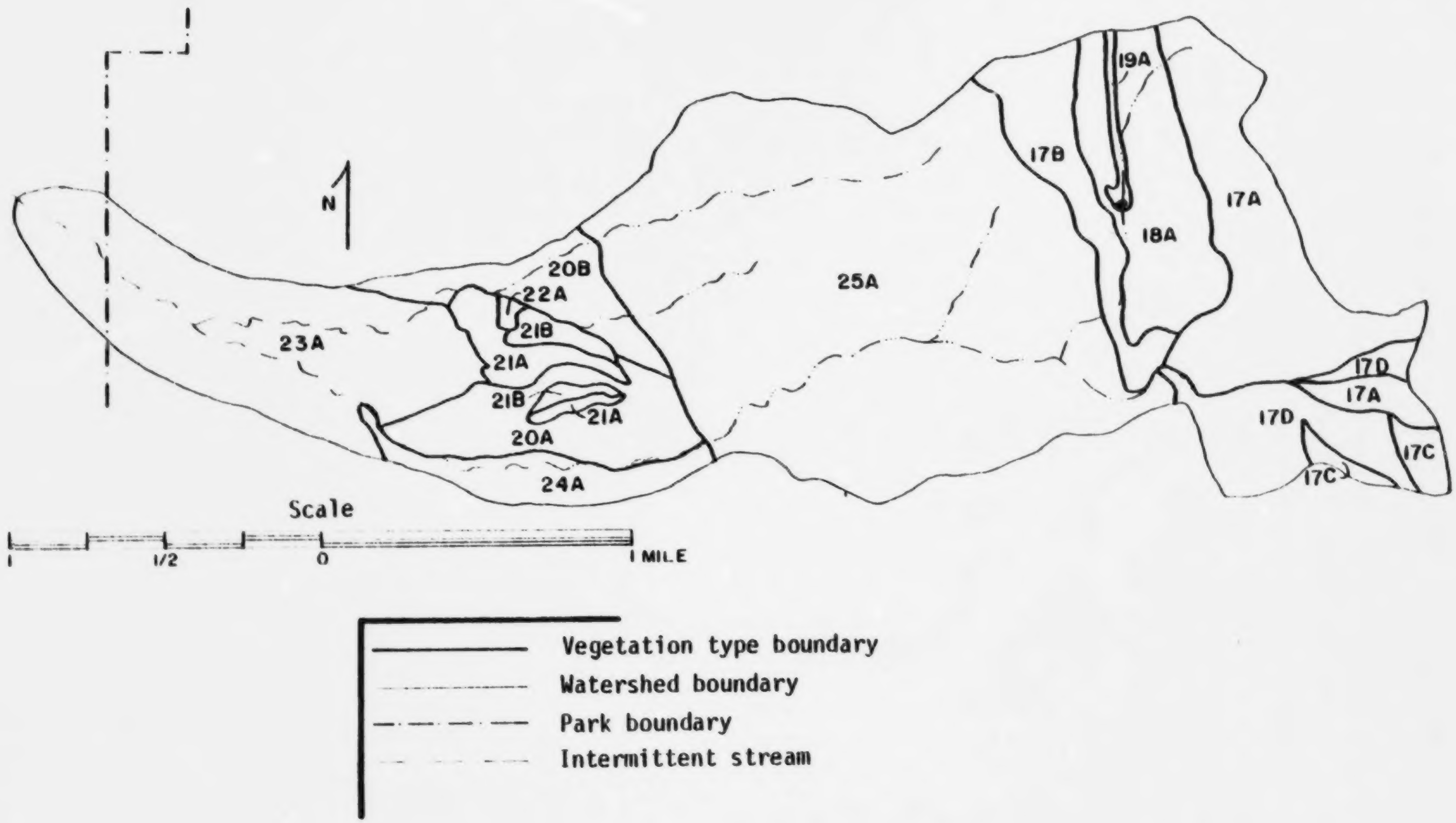

Figure 62. Vegetation Types Watershed 10A6.

## TABLE 60. SITE CHARACTERISTICS OF THE PX RIDGE SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 7000 | 6350-7600 |
| Slope (%) | 47 | 18-65 |
| Ground Cover (%) | | |
| Vegetation | 10 | 6-16 |
| Litter | 27 | 12-58 |
| Small rock | 38 | 16-54 |
| Large rock | 20 | 6-38 |
| Bare ground | 5 | 0-14 |
| Cryptogam | 0 | 0-2 |
| Overstory (%) | | |
| 0-6' | 11 | 0-32 |
| 6-20' | < 1 | 0-6 |
| > 20' | 0 | -- |
| Total | 12 | 0-32 |
| Grasses (%) | 78 | 64-96 |
| Forbs (%) | 9 | 2-22 |
| Shrubs (%) | 13 | 0-28 |

Data based on transects 1-3, 5-7, 84-89, 95-100

Aspects: Eastern, western, northern

TABLE 61. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE JAVELINA BUSH-CURLYLEAF MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6900 | 6500-7400 | | | | | | | | |
| Slope (%) | 50 | 45-57 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 12 | 10-16 | | | | | | | | |
| Litter | 21 | 14-30 | | | | | | | | |
| Small rock | 41 | 28-48 | | | | | | | | |
| Large rock | 22 | 16-32 | | | | | | | | |
| Bare ground | 4 | 0-6 | | | | | | | | |
| Cryptogam | 0 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 10 | 4-22 | | | | | | | | |
| 6-20' | 2 | 0-6 | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 12 | 4-28 | | | | | | | | |
| Muhlenbergia setifolia--curlyleaf muhly | | | 33 | 24-52 | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 11 | 6-22 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 10 | 6-16 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 9 | 2-24 | | | | | | |
| Aristida glauca--blue threeawn | | | 5 | 2-10 | | | | | | |
| Lycurus phleoides--wolftail | | | 5 | 0-8 | | | | | | |
| Condalia ericoides--javelina bush | | | 2 | 0-6 | 3 | 0-10 | | | | |
| Dasylirion leiophyllum--smooth sotol | | | 1 | 0-4 | 2 | 0-6 | | | | |
| Nolina micrantha--smallseed sacahuista | | | 2 | 0-4 | 1 | 0-4 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | < 1 | 0-2 | 2 | 0-4 | | | | |
| Pinus edulis--pinyon pine | | | | | 2 | 0-6 | 2 | 0-6 | | |

Data based on transects 1-3, 5-7

Aspects: Western

Figure 63. Javelina bush-curlyleaf muhly community (PX Ridge Site).

Figure 64. Background: javelina bush-curlyleaf muhly community (PX Ridge Site). Note pinyon pine growing up the small channels traversing this aspect. Midground: PX Flat Site; oneseeded juniper-blue grama community.

TABLE 62. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMALLSEED SACAHUISTA-CURLYLEAF MUHLY-NEW MEXICO FEATHERGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6800 | 6500-6950 | | | | | | | | |
| Slope (%) | 36 | 34-37 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 11 | 10-12 | | | | | | | | |
| Litter | 29 | 20-40 | | | | | | | | |
| Small rock | 44 | 32-52 | | | | | | | | |
| Large rock | 9 | 6-12 | | | | | | | | |
| Bare ground | 7 | 2-14 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 5 | 0-14 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 5 | 0-14 | | | | | | | | |
| *Muhlenbergia setifolia*--curlyleaf muhly | | | 31 | 22-28 | | | | | | |
| *Stipa neomexicana*--New Mexico feathergrass | | | 21 | 10-28 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 16 | 6-34 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 7 | 0-20 | | | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 2 | 0-6 | 5 | 0-14 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | < 1 | 0-2 | < 1 | 0-2 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | < 1 | 0-2 | | | | | | |

Data based on transects 95-97

Aspects: Eastern

Figure 65. Background: smallseed sacahuista-curlyleaf muhly-New Mexico feathergrass community (PX Ridge Site). Foreground: part of the mat muhly-blue grama community inclusion within the PX Flat Site. Midground: PX Flat Site; oneseeded juniper-blue grama community.

Figure 66. Mountain mahogany-New Mexico muhly-New Mexico feathergrass community (PX Ridge Site).

community, but uncommon in the javelina bush-curlyleaf muhly community. New Mexico muhly, littleawn needlegrass and plains lovegrass were infrequent or absent in the smallseed sacahuista-curlyleaf muhly-New Mexico feathergrass community, and wolftail (16%) and sideoats grama (7%) assumed importance. Hawkweed wildbuckwheat was the most common forb, accounting for 6% of the vegetation.

Along the top of the ridge to the west of PX Flat there was more large rock (29%). Curlyleaf muhly (17%) decreased in importance, but was still, together with New Mexico feathergrass (30%), a common grass. Wolftail (2%) also decreased in importance. In general, there were more grass species noted here. Lesquerella spp. (6%), prairie bluets (5%) and Harvard wildbuckwheat (4%) were common forbs. Smallseed sacahuista was still the most common shrub, although sandpaper bush (Mortonia scabrella), smooth sotol and mountain mahogany were also common.

The ridge south of PX Flat had variable topography supporting several plant communities. Throughout the area, forbs made up only 8% of the vegetation. On protected higher elevation northeastern and north northwestern aspects (7360 ft.), the Quercus-Carex-New Mexico muhly community was found (Table 63). Insofar as Quercus spp. (especially Q. undulata) and New Mexico muhly were very common species, this community was similar to the wavyleaf oak-New Mexico muhly community of the Heavily Oaken Slope (49%) site of Watershed 1. However, there was much less overstory (29%) and Quercus spp. (13% in the species composition and 20% in the overstory), and more large rock (20%) in the Quercus-Carex-New Mexico muhly community. In addition, Carex spp. (28%) and littleawn needlegrass (12%) were important in this community; these species were less common in the wavyleaf oak-New Mexico muhly community. Stemmed bitterweed was the most common forb, with smaller amounts of green puccoon (Lithospermum viride), prickleaf gilia and lewis flax (Linum lewisii).

On protected western aspects (7400 ft.) opposite the Quercus-Carex-New Mexico muhly community, Quercus spp. were much less important (6% in the species composition and 12% in the overstory). Pinyon pine also occurred. New Mexico muhly, Carex spp. and littleawn needlegrass

TABLE 63. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE *QUERCUS*-*CAREX*-NEW MEXICO MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7300 | 7000-7600 | | | | | | | | |
| Slope (%) | 62 | 60-64 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 10 | 8-12 | | | | | | | | |
| Litter | 48 | 38-58 | | | | | | | | |
| Small rock | 17 | 16-18 | | | | | | | | |
| Large rock | 20 | 10-30 | | | | | | | | |
| Bare ground | 5 | 4-6 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 29 | 26-32 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 29 | 26-32 | | | | | | | | |
| *Carex* spp.--sedge | | | 28 | 20-36 | | | | | | |
| *Muhlenbergia setifolia*--curlyleaf muhly | | | 22 | 18-26 | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 12 | 10-14 | | | | | | |
| *Quercus* spp. & *Q. undulata*--oaks & wavyleaf oak | | | 13 | 10-16 | 20 | 16-24 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | 3 | 2-4 | 4 | 4 | | | | |
| *Chrysothamnus spathulatus*--rabbitbrush | | | 3 | 2-4 | 1 | 0-2 | | | | |
| *Choisya dumosa*--starleaf Mexican orange | | | 4 | 2-6 | | | | | | |

Data based on transects 85, 88

Aspects: Northeastern, north northwestern, protected western were still the most common grasses. Allium spp. was the most common forb.

On the rest of this ridge, the mountain mahogany-New Mexico muhly-New Mexico feathergrass community was found (Table 64, Figure 66). Quercus spp. and wavyleaf oak were infrequent or absent. Mountain mahogany was the most important shrub, although javelina bush was also common, with smaller amounts of smooth sotol and smallseed sacahuista. In the understory, New Mexico muhly (29%), New Mexico feathergrass (16%) and littleawn needlegrass (15%) were the most common grasses. There was little Carex spp. (2%). Stemmed bitterweed (3%), Hawkweed wild-buckwheat (2%), longstalk greenthread (1%) and Allium spp. (1%) were the most common forbs.

## PX FLAT--SITE

The lower, level area of PX Flat made up the PX Flat site. Further from the tank in the wooded area, there was 36% litter, 11% vegetative ground cover, 20% small rock and 32% bare ground. Total overstory averaged 21% with shrubs and trees making up 7% of the vegetation.

The oneseeded juniper-blue grama community was found in this area (Table 65, Figures 67, 68). Oneseeded juniper (Juniperus monosperma) was the dominant overstory species, although many other species were present. Although pinyon pine was present, it was infrequent in the samples. Other species included Guadalupe mountainlaurel (Sophora gypsophilia var. quadalupensis), rabbitbush (Chrysothamnus spathulatus), apacheplume and Torrey yucca (Yucca torreyi); however, none of these species were frequent. Blue grama generally dominated the understory, although in some areas it was not found. Other important grasses included sideoats grama, hairy grama (Bouteloua hirsuta), wolftail and blue threeawn. Forbs made up 9% of the vegetation. Common species included Euphorbia spp. and Chamaesaracha spp.

Around the tank, and northward along a narrow corridor from the tank, there was a small inclusion within the PX Flat site with 59% litter, 25% bare ground, 18% vegetative ground cover and no overstory. Despite first impressions, this area is different from the Meadow site of Watershed 1. The mat muhly-blue grama community (Table 66, Figure 69) was found here. Grasses comprised 95% of the vegetation. In

## TABLE 64. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE MOUNTAIN MAHOGANY-NEW MEXICO MUHLY-NEW MEXICO FEATHERGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7050 | 6300-7400 | | | | | | | | |
| Slope (%) | 56 | 50-65 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 7 | 6-10 | | | | | | | | |
| Litter | 21 | 20-22 | | | | | | | | |
| Small rock | 49 | 44-55 | | | | | | | | |
| Large rock | 20 | 16-24 | | | | | | | | |
| Bare ground | 3 | 0-4 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 12 | 8-16 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 12 | 8-16 | | | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 29 | 26-36 | | | | | | |
| Stipa neomexicana--New Mexico feathergrass | | | 16 | 4-28 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 15 | 10-18 | | | | | | |
| Carex spp.--sedge | | | 2 | 0-4 | | | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 3 | 2-6 | 5 | 4-6 | | | | |
| Condalia ericoides--javelina bush | | | 3 | 2-4 | 3 | 0-6 | | | | |
| Nolina micrantha--smallseed sacahuista | | | 2 | 0-4 | 1 | 0-2 | | | | |
| Quercus undulata--wavyleaf oak | | | 1 | 0-2 | < 1 | 0-2 | | | | |

Data based on transects 86, 87, 89

Aspects: Northern

TABLE 65. SITE CHARACTERISTICS OF THE PX FLAT SITE AND SPECIES COMPOSITION OF THE ONESEEDED JUNIPER-BLUE GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6450 | 6400-6500 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 11 | 10-12 | | | | | | | | |
| Litter | 36 | 24-54 | | | | | | | | |
| Small rock | 20 | 2-50 | | | | | | | | |
| Large rock | 1 | 0-4 | | | | | | | | |
| Bare ground | 32 | 12-52 | | | | | | | | |
| Cryptogam | < 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 11 | 2-18 | | | | | | | | |
| 6-20' | 10 | 6-16 | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 21 | 8-28 | | | | | | | | |
| Grasses (%) | 84 | 60-100 | | | | | | | | |
| Forbs (%) | 9 | 0-18 | | | | | | | | |
| Shrubs (%) | 7 | 0-24 | | | | | | | | |
| *Bouteloua gracilis*--blue grama | | | 30 | 0-50 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 11 | 0-20 | | | | | | |
| *Bouteloua hirsuta*--hairy grama | | | 7 | 0-16 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 6 | 0-14 | | | | | | |
| *Aristida glauca*--blue threeawn | | | 5 | 0-12 | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 5 | 0-24 | | | | | | |
| *Juniperus monosperma*--oneseeded juniper | | | < 1 | 0-2 | 6 | 0-16 | 9 | 4-16 | | |
| *Sophora gypsophila* var. *guadalupensis*--Guadalupe mountainlaurel | | | 1 | 0-6 | 2 | 0-8 | | | | |
| *Chrysothamnus spathulatus*--rabbitbrush | | | 2 | 0-4 | | | | | | |
| *Fallugia paradoxa*--Apacheplume | | | < 1 | 0-2 | < 1 | 0-2 | | | | |
| *Yucca torreyi*--Torrey yucca | | | < 1 | 0-2 | < 1 | 0-2 | | | | |

Data based on transects 4, 90, 91, 101, 102

Aspects: None (level)

Figure 67. Oneseeded juniper-blue grama community (PX Flat Site).

Figure 68. Oneseeded juniper-blue grama community (PX Flat Site). Background: PX Ridge Site; Western (left) and Northern (right) aspects.

TABLE 66. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE MAT MUHLY-BLUE GRAMA COMMUNITY INCLUSION IN THE PX FLAT SITE

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6450 | 6400-6500 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 18 | 16-20 | | | | | | | | |
| Litter | 59 | 42-80 | | | | | | | | |
| Small rock | 0 | -- | | | | | | | | |
| Large rock | 0 | -- | | | | | | | | |
| Bare ground | 23 | 2-38 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 0 | -- | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 0 | -- | | | | | | | | |
| Grasses (%) | 95 | 88-98 | | | | | | | | |
| Forbs (%) | 4 | 2-8 | | | | | | | | |
| Shrubs (%) | 1 | 0-4 | | | | | | | | |
| *Muhlenbergia repens*--mat muhly | | | 52 | 34-80 | | | | | | |
| *Bouteloua gracilis*--blue grama | | | 19 | 8-26 | | | | | | |
| *Panicum obtusum*--vine-mesquite | | | 13 | 2-28 | | | | | | |

Data based on transects 92-94

Aspects: None (level)

Figure 69. Mat muhly-blue grama community (inclusion within PX Flat Site).

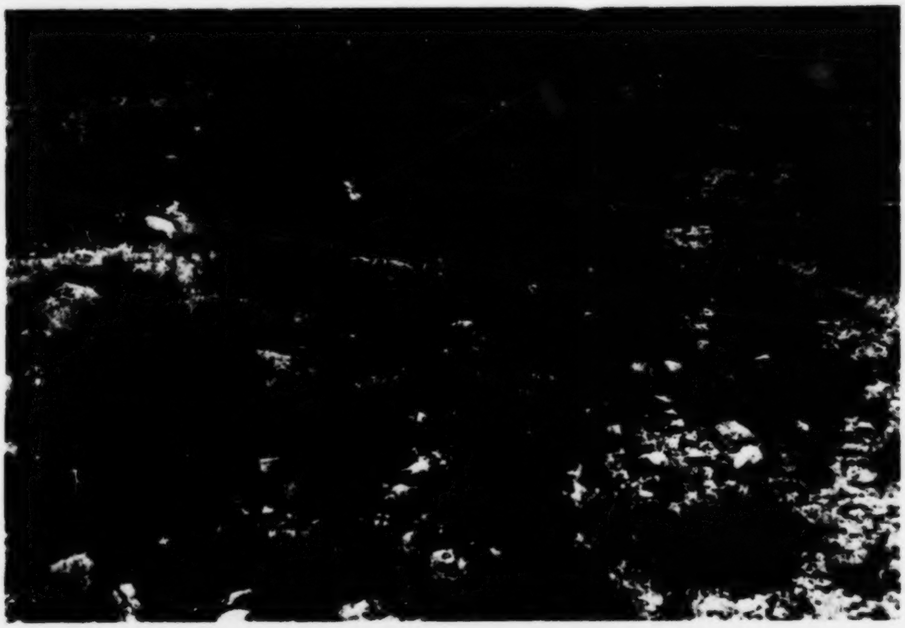

Figure 70. Creosote Site; creosotebush-*Sporobolus*-black grama community.

some areas, mat muhly grew in very dense stands, making up 80% of the vegetation. Blue grama and vine-mesquite (Panicum obtusum) also occurred in the area, and tended to show clumped distributions. Finestem needlegrass was locally abundant near the perimeter of the tank. Few other grasses were found. Cholla and Yucca spp. were present.

The lower region of this watershed is a fluvial outwash plain. Sampling was completed during a relatively dry period of the year (mid July), and several remarks regarding plant identification are apposite. None of the various species of Sporobolus recorded in the park (S. cryptandrus, S. flexuosis, S. giganteus, S. contractus, S. wrightii, S. nealleyi and S. aroides) were in flower at the time, and so identification to the species level was not possible. This was also true of Aristida spp. Consequently, species belonging to these two groups will henceforth be referred to generically. Bunting (1978) recorded A. pansa throughout much of the area, and our species may have corresponded to this. Many of the forbs were dead and dessicated, and so identification of species of Nama, Cryptantha and Lesquerella was also not possible. While not verifiable, it is suspected that our species were probably N. stevensii, C. crassisepala and L. fendleri.

## CREOSOTE--SITE

The Creosote site occurred at elevations ranging from 3950-4400 ft., with slopes averaging 11% (range 6-16%) (Table 67). This region roughly corresponds to the eastern half of the lower end of the watershed. This site characteristically had 56% small rock and 18% bare ground. Over 52% of the species composition was forbs, with 39% grasses and 9% shrubs.

Two very different plant communities were found in the Creosote site, distinguishable both by overstory and understory species. The creosotebush-Sporobolus-black grama community (Table 68, Figure 70) was found to the south of the rock inclusion in the site. Creosotebush (Larrea tridentata) was the dominant species with regard to overstory, contributing 8% to a total of 13%. Range ratany (Krameria glandulosa) was as important as creosotebush with regard to species composition (2%) but accounted for only 3% of the overstory. Other shrubs included skeleton goldeneye, mariola parthenium and honey

## TABLE 67. SITE CHARACTERISTICS OF THE CREOSOTE SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 4100 | 3950-4400 |
| Slope (%) | 11 | 6-16 |
| Ground Cover (%) | | |
| Vegetation | 5 | 0-8 |
| Litter | 16 | 8-24 |
| Small rock | 56 | 28-68 |
| Large rock | 5 | 0-10 |
| Bare ground | 18 | 8-38 |
| Cryptogam | < 1 | 0-2 |
| Overstory (%) | | |
| 0-6' | 10 | 0-20 |
| 6-20' | 0 | -- |
| > 20' | 0 | -- |
| Total | 10 | 0-20 |
| Grasses (%) | 39 | 14-66 |
| Forbs (%) | 52 | 16-70 |
| Shrubs (%) | 9 | 0-8 |

Data based on transects 1-6, 13, 14, 18, 19, 22-25, 36-38, 40

Aspects: Western

TABLE 68. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE CREOSOTEBUSH-*SPOROBOLUS*-BLACK GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 4150 | 3950-4400 | | | | | | | | |
| Slope (%) | 11 | 8-16 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 4 | 0-6 | | | | | | | | |
| Litter | 17 | 8-24 | | | | | | | | |
| Small rock | 57 | 28-68 | | | | | | | | |
| Large rock | 8 | 2-34 | | | | | | | | |
| Bare ground | 14 | 8-20 | | | | | | | | |
| Cryptogam | < 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 13 | 4-20 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 13 | 4-20 | | | | | | | | |
| *Sporobolus* spp.--dropseed | | | 12 | 4-22 | | | | | | |
| *Bouteloua eriopoda*--black grama | | | 11 | 2-32 | | | | | | |
| *Erioneuron pulchellum*--fluffgrass | | | 8 | 0-24 | | | | | | |
| *Tridens muticus*--slim tridens | | | 7 | 0-18 | | | | | | |
| *Aristida* spp.--threeawn | | | 3 | 0-12 | | | | | | |
| *Larrea tridentata*--creosotebush | | | 2 | 2-4 | 8 | 2-14 | | | | |
| *Krameria glandulosa*--range ratany | | | 2 | 0-6 | 3 | 0-12 | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 1 | 0-4 | 1 | 0-2 | | | | |
| *Parthenium incanum*--mariola parthenium | | | 1 | 0-2 | 1 | 0-6 | | | | |
| *Prosopis glandulosa*--honey mesquite | | | < 1 | 0-2 | 1 | 0-6 | | | | |

Data based on transects 1-6, 36-38, 40

Aspects: Western

mesquite (Prosopis glandulosa), although a variety of species were present. Grasses comprised 41% of the vegetation. Sporobolus spp. (12%) and black grama (Bouteloua eriopoda) (11%) were the most important species, although fluffgrass (Erioneuron pulchellum) (8%), slim tridens (Tridens muticus) (7%) and Aristida spp. (3%) were also common. Few other species were found. Fifty percent of the vegetation was made up of forbs. Prickleaf dyssodia (Dyssodia acerosa), common dyssodia (Dyssodia pentachaeta) and wooly Indian wheat (Plantago patagonica) were the most common species, accounting for 39% of the vegetation. Also present were Nama spp., plains dozedaisy (Aphanostephus ramosissimus), and in smaller amounts, pepperweed (Lepidum oblongum), Cryptantha spp. and Lesquerella spp., among others.

The range ratany-skeleton goldeneye-fluffgrass community (Table 69, Figure 71) was found to the north and east of the rock outcrop inclusion in the site. Total overstory in this community (6%) was much less than in the creosotebush-Sporobolus-black grama community, and creosotebush made up less of the species composition (0.8%) and overstory (1%). The dominant shrubs were range ratany and skeleton goldeneye, which combined to make up 4% of the species composition and 3% of the overstory. Other shrubs included Engelmann pricklypear (Opuntia engelmannii), cholla and Torrey yucca. Grasses comprised 38% of the vegetation, the most important being fluffgrass (22%). Aristida spp. and Sporobolus spp. each contributed 5% to the species composition. Black grama (2%) was infrequent. Prickleaf and common dyssodia combined to account for 39% of the vegetation. Nama spp., rough coldenia (Coldenia hispidissima) and wooly Indian wheat were other common species.

## OUTCROP--SITE

An interbedded rock outcrop occurred roughly between the creosotebush-Sporobolus-black grama and range ratany-skeleton goldeneye-fluffgrass communities. This area constituted the Outcrop site (Table 70). Slopes were steeper (25%), with less vegetative ground cover (3%), small rock (32%) and bare ground (5%), and more large rock (17%) and cryptogam (6%), than the Creosote site.

## TABLE 69. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE RANGE RATANY-SKELETON GOLDENEYE-FLUFFGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 4050 | 3950-4300 | | | | | | | | |
| Slope (%) | 11 | 6-16 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 6 | 2-8 | | | | | | | | |
| Litter | 14 | 8-18 | | | | | | | | |
| Small rock | 56 | 40-66 | | | | | | | | |
| Large rock | 2 | 0-10 | | | | | | | | |
| Bare ground | 22 | 12-38 | | | | | | | | |
| Cryptogam | < 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 6 | 0-12 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 6 | 0-12 | | | | | | | | |
| Erioneuron pulchellum--fluffgrass | | | 22 | 8-32 | | | | | | |
| Sporobolus spp.--dropseed | | | 5 | 0-18 | | | | | | |
| Aristida spp.--threeawn | | | 5 | 0-10 | | | | | | |
| Tridens muticus--slim tridens | | | 3 | 0-8 | | | | | | |
| Bouteloua eriopoda--black grama | | | 2 | 0-8 | | | | | | |
| Krameria glandulosa--range ratany | | | 2 | 0-4 | 2 | 0-6 | | | | |
| Viguiera stenoloba--skeleton goldeneye | | | 2 | 0-10 | 1 | 0-8 | | | | |
| Larrea tridentata--creosotebush | | | 1 | 0-2 | 1 | 0-2 | | | | |
| Coldenia canescens--gray coldenia | | | 1 | 0-4 | < 1 | 0-2 | | | | |

Data based on transects 13, 14, 18, 19, 22-25

Aspects: Western

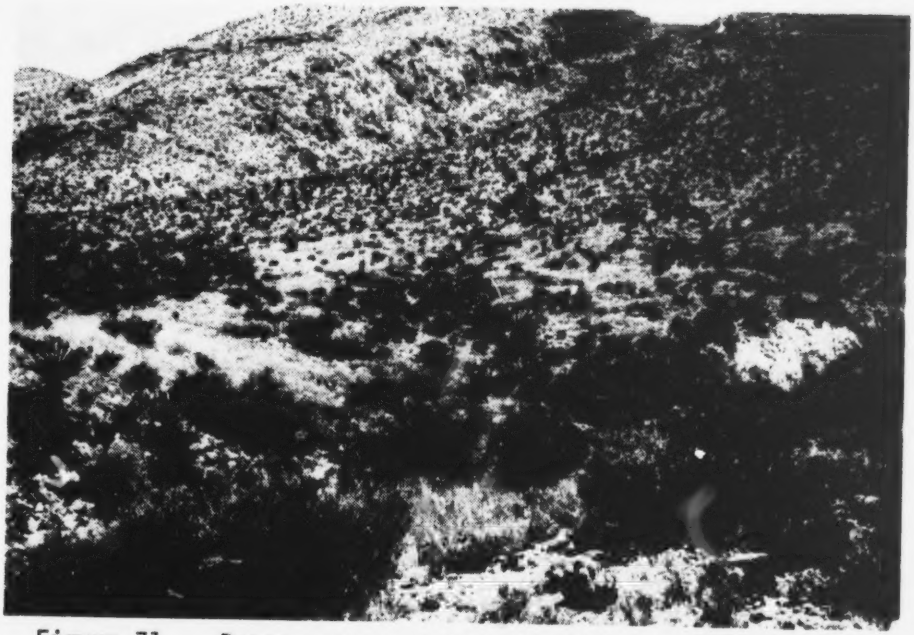

Figure 71. Range ratany-skeleton goldeneye-fluffgrass community (Creosote Site).

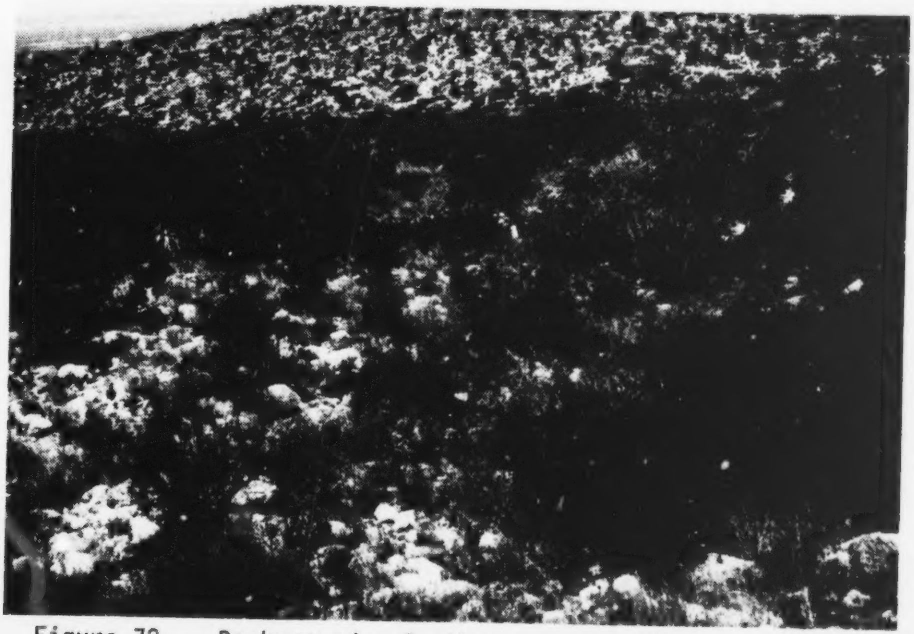

Figure 72. Background: Southern aspect of the Outcrop Site; skeleton goldeneye-gray coldenia-slim tridens community.
Foreground: Creosote Site; creosotebush-Sporobolus-black grama community.

TABLE 70. SITE CHARACTERISTICS OF THE OUTCROP SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 4150 | 3960-4160 |
| Slope (%) | 25 | 12-50 |
| Ground Cover (%) | | |
| Vegetation | 3 | 0-6 |
| Litter | 14 | 6-28 |
| Small rock | 32 | 23-46 |
| Large rock | 33 | 26-45 |
| Bare ground | 12 | 0-20 |
| Cryptogam | 6 | 2-26 |
| Overstory (%) | | |
| 0-6' | 10 | 5-14 |
| 6-20' | 0 | -- |
| > 20' | 0 | -- |
| Total | 10 | 5-14 |
| Grasses (%) | 54 | 40-68 |
| Forbs (%) | 30 | 18-44 |
| Shrubs (%) | 16 | 8-26 |

Data based on transects 7-12, 15-17

Aspects: Northern, southern

Northern and southern exposures supported different vegetation. On the southern aspects, the skeleton goldeneye-gray coldenia-slim tridens community occurred (Table 71, Figure 72). Other shrubs included ocotillo (Fouquieria splendens), datil yucca (Yucca baccata) and smooth sotol. Creosotebush and range ratany were relatively unimportant. Slim tridens (23%) dominated the understory. Warnock grama (Bouteloua warnockii), black grama, fluffgrass, Sporobolus spp. and Aristida spp. were also present in amounts ranging from 4-6%. The most common forbs were prickleaf and common dyssodias, which combined to account for 10% of the species composition. Rough coldenia (8%), Nama spp. (7%) and Lesquerella spp. (5%) were also common, with smaller amounts of Polygala spp., Euphorbia spp., hedeoma and mesa greggia (Nerisyrenia camporum).

Northern aspects supported a skeleton goldeneye-smooth sotol-Warnock grama-slim tridens community (Table 72, Figure 73). This community was similar to the skeleton goldeneye-gray coldenia-slim tridens community insofar as skeleton goldeneye was the dominant shrub. However, gray coldenia (Coldenia canescens) was absent, and smooth sotol was more important. Engelmann pricklypear and mariola parthenium were also common. Range ratany and creosotebush were not found. Greater amounts of Warnock grama (17%), black grama (12%) and Stipa spp. (6%) also distinguished the skeleton goldeneye-smooth sotol-Warnock grama-slim tridens community from the skeleton goldeneye-gray coldenia-slim tridens community. However, Aristida spp. and Sporobolus spp. were similar in both communities. Forbs provided another difference between the communities. Hedeoma (11%) was most common in the skeleton goldeneye-smooth sotol-Warnock grama-slim tridens community. Also, prickleaf and common dyssodias were relatively unimportant (2%), and there were smaller amounts of Lesquerella spp. (0.3%), Nama spp. (0.8%) and rough coldenia (3%) in this community.

A small creosotebush-pepperweed-Cryptantha community was found in the site. Site characteristics were anomalous: 58% bare ground, 20% small rock, 17% litter, 2% vegetative ground cover, 0% large rock, 3% cryptogam and 30% overstory (Table 73, Figure 74). This inclusion did not fit any site found in lower 10A6. Forbs made up 94% of the vegetation with only 1% grasses. Creosotebush accounted for 29% of the

## TABLE 71. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SKELETON GOLDENEYE-GRAY COLDENIA-SLIM TRIDENS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 4150 | 4000-4160 | | | | | | | | |
| Slope (%) | 17 | 12-19 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 2 | 0-4 | | | | | | | | |
| Litter | 12 | 6-18 | | | | | | | | |
| Small rock | 35 | 22-46 | | | | | | | | |
| Large rock | 29 | 26-32 | | | | | | | | |
| Bare ground | 15 | 8-20 | | | | | | | | |
| Cryptogam | 7 | 2-26 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 11 | 8-14 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 11 | 8-14 | | | | | | | | |
| *Tridens muticus*--slim tridens | | | 23 | 14-24 | | | | | | |
| *Bouteloua warnockii*--Warnock grama | | | 6 | 4-8 | | | | | | |
| *Aristida* spp.--threeawn | | | 6 | 2-10 | | | | | | |
| *Sporobolus* spp.--dropseed | | | 5 | 2-10 | | | | | | |
| *Bouteloua eriopoda*--black grama | | | 5 | 0-12 | | | | | | |
| *Erioneuron pulchellum*--fluffgrass | | | 4 | 0-10 | | | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 5 | 0-10 | 4 | 2-6 | | | | |
| *Coldenia canescens*--gray coldenia | | | 4 | 2-10 | 2 | 0-4 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 1 | 0-2 | 1 | 0-6 | | | | |
| *Fouquieria splendens*--ocotillo | | | 1 | 0-4 | 2 | 0-6 | | | | |
| *Yucca torreyi*--Torrey yucca | | | 1 | 0-2 | 1 | 0-4 | | | | |
| *Krameria glandulosa*--range ratany | | | 1 | 0-4 | < 1 | 0-2 | | | | |

Data based on transects 7-12

Aspects: Southern

TABLE 72. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SKELETON GOLDENEYE-SMOOTH SOTOL-WARNOCK GRAMA-SLIM TRIDENS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 4100 | 4000-4160 | | | | | | | | |
| Slope (%) | 28 | 27-50 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 3 | 0-6 | | | | | | | | |
| Litter | 20 | 12-28 | | | | | | | | |
| Small rock | 28 | 23-32 | | | | | | | | |
| Large rock | 40 | 36-45 | | | | | | | | |
| Bare ground | 5 | 0-14 | | | | | | | | |
| Cryptogam | 4 | 2-5 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 8 | 5-10 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 8 | 5-10 | | | | | | | | |
| *Bouteloua warnockii*--Warnock grama | | | 17 | 8-30 | | | | | | |
| *Tridens muticus*--slim tridens | | | 14 | 3-24 | | | | | | |
| *Bouteloua eriopoda*--black grama | | | 12 | 8-15 | | | | | | |
| *Sporobolus* spp.--dropseed | | | 7 | 4-8 | | | | | | |
| *Aristida* spp.--threeawn | | | 6 | 0-15 | | | | | | |
| *Stipa* spp.--needlegrass | | | 6 | 3-10 | | | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 5 | 0-8 | 2 | 0-4 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 3 | 0-6 | 4 | 0-10 | | | | |
| *Yucca elata*--soaptree yucca | | | 1 | 0-2 | 1 | 0-2 | | | | |
| *Opuntia engelmannii*--Engelmann pricklypear | | | 2 | 0-3 | | | | | | |

Data based on transects 15, 16, 17

Aspects: Northern

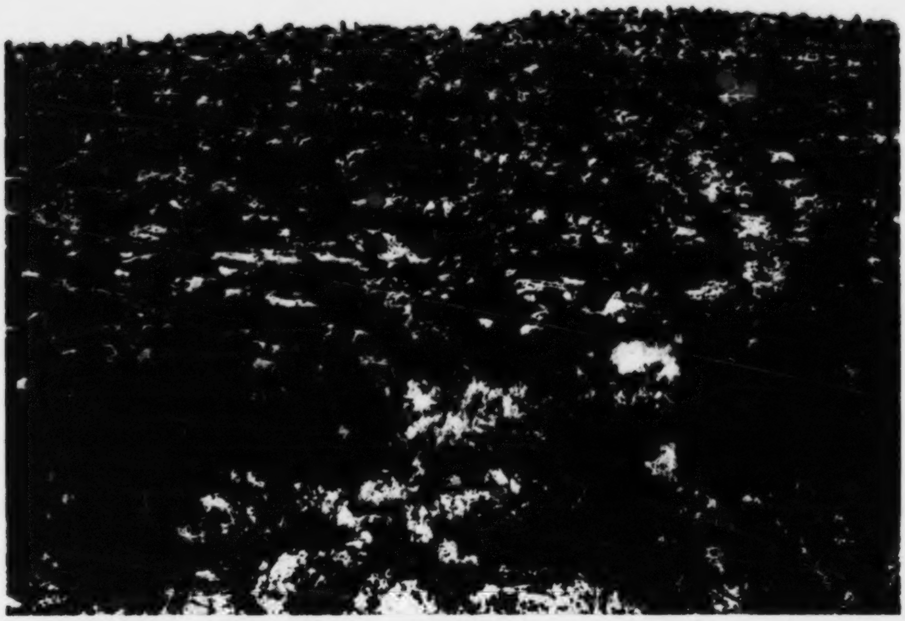

Figure 73. Background: Northern aspect of the Outcrop Site; skeleton goldeneye-smooth sotol-Warnock grama-slim tridens community.

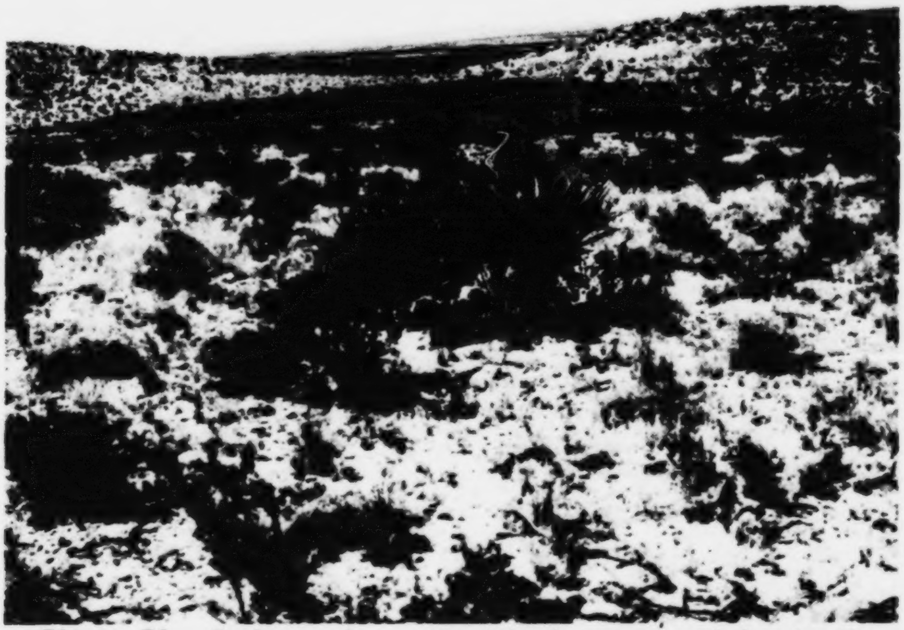

Figure 74. Background: creosotebush-pepperweed-Cryptantha community inclusion (dark patch of vegetation below saddle).
Foreground: range ratany-skeleton goldeneye-fluffgrass community of Creosote Site.

## TABLE 73. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE CREOSOTEBUSH-PEPPERWEED-CRYPTANTHA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 4050 | 4050 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 2 | 0-4 | | | | | | | | |
| Litter | 17 | 16-18 | | | | | | | | |
| Small rock | 20 | 20 | | | | | | | | |
| Large rock | 0 | -- | | | | | | | | |
| Bare ground | 58 | 56-60 | | | | | | | | |
| Cryptogam | 3 | 2-4 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 30 | 26-34 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 30 | 26-34 | | | | | | | | |
| Grasses (%) | 1 | 0-2 | | | | | | | | |
| Forbs (%) | 94 | 94 | | | | | | | | |
| Shrubs (%) | 5 | 4-6 | | | | | | | | |
| Larrea tridentata--creosotebush | | | 2 | 0-4 | 29 | 26-32 | | | | |
| Parthenium argentatum--guayule | | | 2 | 0-2 | | | | | | |
| Prosopis glandulosa--honey mesquite | | | | | 1 | 0-2 | | | | |
| Lepidium oblongum--pepperweed | | | 33 | 28-38 | | | | | | |
| Cryptantha spp. | | | 29 | 20-38 | | | | | | |
| Nama spp. | | | 14 | 8-20 | | | | | | |
| Aphanostephus ramosissimus--plains dozedaisy | | | 8 | 8 | | | | | | |
| Dyssodia acerosa & D. pentachaeta--prickleaf and common dyssodia | | | 6 | 0-2 | | | | | | |

Data based on transects 20, 21

Aspects: None (level)

overstory. Guayule (*Parthenium argentatum*) and honey mesquite were also present in small amounts. The most common forbs were pepperweed (33%) and *Cryptantha* spp. (29%), with smaller amounts of *Nama* spp. (14%), plains dozedaisy (8%), and prickleaf and common dyssodias (6%).

GYPSUM--SITE

The western half of the lower end of the watershed (3705-3950 ft.) has variable soils, and some areas are gypsiferous. This area constituted the Gypsum site. The vegetation reflected these soil influences, and was mapped into a range ratany-creosotebush-*Dyssodia*-wooly Indian wheat community complex (Table 74, Figures 75, 76 and 77). As a whole, the site was characterized by 57% bare ground, often in the form of a gyp crust. Only 4% of the ground was covered by vegetation. Forbs composed 77% of the vegetation. Slopes averaged 5% (range 3-10%).

Range ratany was common throughout the site with creosotebush and jimmyweed (*Isocoma wrightii*) locally abundant. On the average, there was 22% prickleaf and common dyssodias, and 20% wooly Indian wheat. Rough coldenia (9%) was also common. Phacelia (*Phacelia intermedia*) and *Cryptantha* spp. were locally abundant. Few grasses were found (12%). Sometimes isolated locations supported dense stands of fluffgrass and black grama. Along with these species, *Aristida* spp. and *Sporobolus* spp. were the most frequently encountered grasses.

The soils in the extreme western end of the watershed are sandier, with less gypsum; mesquite is more common here and creosotebush is less common.

CHANNEL--SITE

Along the southern boundary of the watershed, the landscape is dissected by channels into rough topography. This area made up the Channel site. There was little vegetative ground cover (2%). However, the overstory was the greatest on this site (11%), and the site also had the most litter (24%). Large rocks accounted for 30% of the ground cover.

The creosotebush-black grama community was found on this site (Table 75, Figure 78). Creosotebush dominated the overstory, while Engelmann pricklypear and mariola parthenium were the most common

TABLE 74. SITE CHARACTERISTICS OF THE GYPSUM SITE AND SPECIES COMPOSITION OF THE RANGE RATANY-CREOSOTEBUSH-*DYSSODIA*-WOOLY INDIAN WHEAT COMMUNITY COMPLEX

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 3900 | 3750-3950 | | | | | | | | |
| Slope (%) | 5 | 3-10 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 4 | 0-6 | | | | | | | | |
| Litter | 11 | 2-22 | | | | | | | | |
| Small rock | 22 | 2-48 | | | | | | | | |
| Large rock | 2 | 0-8 | | | | | | | | |
| Bare ground | 57 | 38-70 | | | | | | | | |
| Cryptogam | 4 | 0-36 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 5 | 0-14 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 5 | 0-14 | | | | | | | | |
| Grasses (%) | 12 | 0-26 | | | | | | | | |
| Forbs (%) | 77 | 58-98 | | | | | | | | |
| Shrubs (%) | 11 | 2-52 | | | | | | | | |
| *Erioneuron pulchellum*--fluffgrass | | | 6 | 0-32 | | | | | | |
| *Aristida* spp.--threeawn | | | 3 | 0-6 | | | | | | |
| *Sporobolus* spp.--dropseed | | | 1 | 0-6 | | | | | | |
| *Bouteloua eriopoda*--black grama | | | 1 | 0-8 | | | | | | |
| *Krameria glandulosa*--range ratany | | | 4 | 0-10 | 1 | 0-8 | | | | |
| *Larrea tridentata*--creosotebush | | | 1 | 0-2 | 1 | 0-10 | | | | |
| *Yucca torreyi*--Torrey yucca | | | 1 | 0-4 | 1 | 0-4 | | | | |
| *Prosopis glandulosa*--honey mesquite | | | < 1 | 0-2 | 1 | 0-4 | | | | |

Data based on transects 26-33, 41-44

Aspects: Western to none (level)

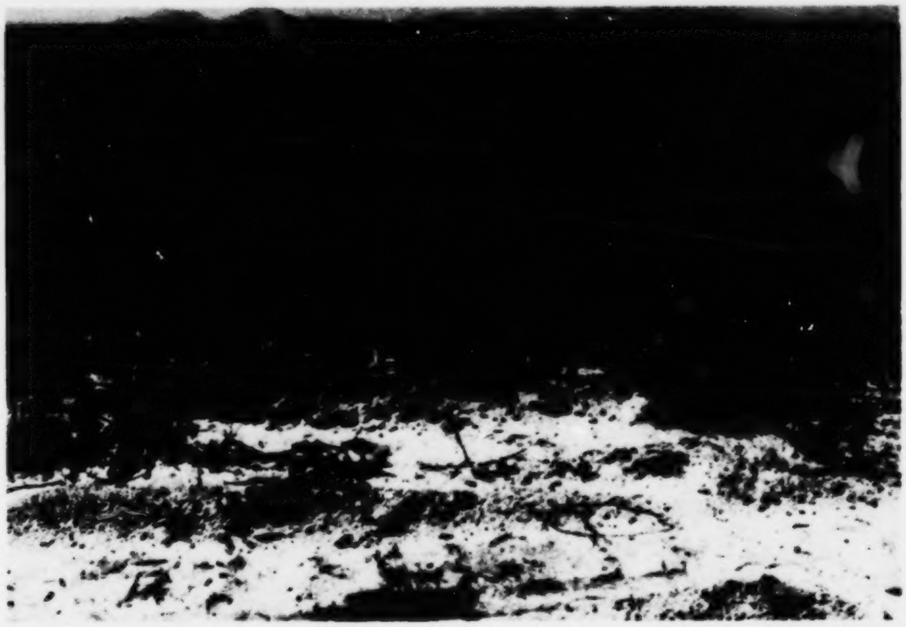

Figure 75. Gypsum Site; range ratany-creosotebush-Dyssodia-wooly Indian wheat community complex. Shrubs in background are mostly creosotebush. Understory vegetation is almost entirely Phacelia intermedia (foreground is a road).

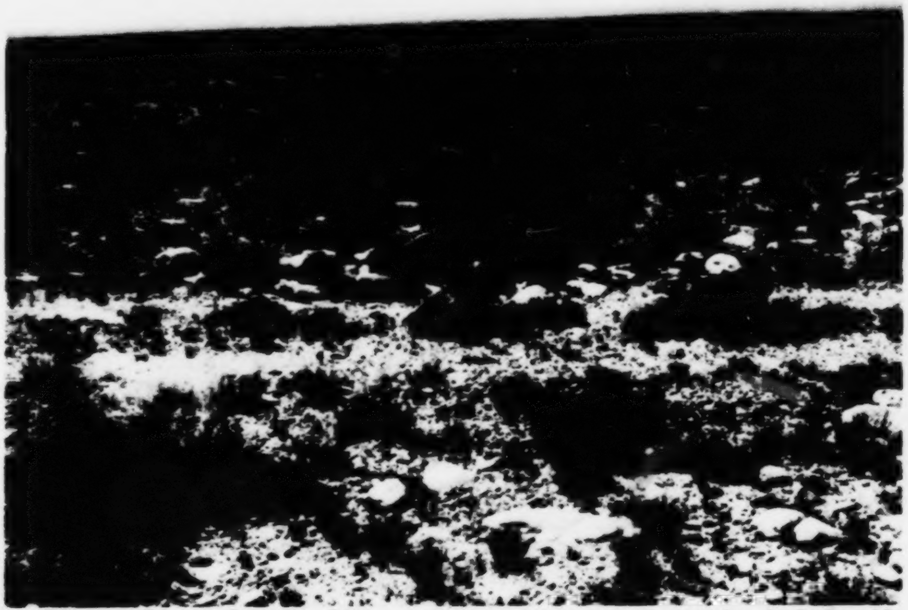

Figure 76. Gypsum Site; range ratany-creosotebush-Dyssodia-wooly Indian wheat community complex. Compare vegetation and ground cover in this figure with Figure 75.

Figure 77. Gypsum Site; range ratany-creosotebush-*Dyssodia*-wooly Indian wheat community complex. Compare with Figures 75 and 76.

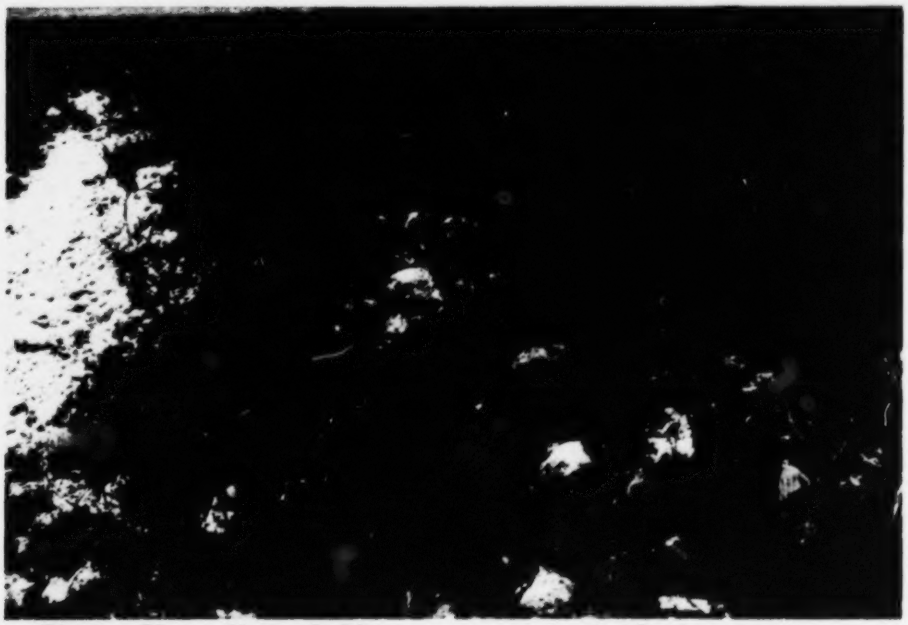

Figure 78. Channel Site; creosotebush-black grama community.

TABLE 75. SITE CHARACTERISTICS OF THE CHANNEL SITE AND SPECIES COMPOSITION OF THE CREOSOTEBUSH-BLACK GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 4050 | 3950-4100 | | | | | | | | |
| Slope (%) | 8 | 7-9 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 2 | 2 | | | | | | | | |
| Litter | 24 | 16-32 | | | | | | | | |
| Small rock | 24 | 18-32 | | | | | | | | |
| Large rock | 30 | 26-32 | | | | | | | | |
| Bare ground | 19 | 16-22 | | | | | | | | |
| Cryptogam | 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 11 | 8-14 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 11 | 8-14 | | | | | | | | |
| Grasses (%) | 62 | 54-74 | | | | | | | | |
| Forbs (%) | 27 | 16-38 | | | | | | | | |
| Shrubs (%) | 11 | 8-14 | | | | | | | | |
| Bouteloua eriopoda--black grama | | | 45 | 34-58 | | | | | | |
| Sporobolus spp.--dropseed | | | 7 | 4-8 | | | | | | |
| Tridens muticus--slim tridens | | | 3 | 0-8 | | | | | | |
| Erioneuron pulchellum--fluffgrass | | | 2 | 0-4 | | | | | | |
| Setaria leucopila--plains bristlegrass | | | 2 | 0-6 | | | | | | |
| Leptoloma cognatum--fall witchgrass | | | 1 | 0-4 | | | | | | |
| Larrea tridentata--creosotebush | | | 1 | 0-2 | 5 | 0-8 | | | | |
| Viguiera stenoloba--skeleton goldeneye | | | 1 | 0-2 | 3 | 0-6 | | | | |
| Opuntia engelmannii--Engelmann pricklypear | | | 3 | 2-4 | 1 | 0-2 | | | | |
| Parthenium incanum--mariola parthenium | | | 3 | 0-4 | | | | | | |

Data based on transects 34, 35, 39

Aspects: Western to none (level)

shrubs in the species composition. Skeleton goldeneye, cholla, honey mesquite, guayule, *Ephedra* spp., rabbitbrush and smooth sotol were also found. Black grama was the most important understory species, accounting for 45% of the vegetation. *Sporobolus* spp. (7%) was also common, along with smaller amounts of slim tridens, fluffgrass, plains bristlegrass (*Setaria leucopila*), fall witchgrass (*Leptoloma cognatum*) and bush muhly (*Muhlenbergia porteri*). Prickleaf and common dyssodias, plains dozedaisy, pepperweed and wooly Indian wheat were the most common forbs, combining to make up 23% of the vegetation.

## WATERSHEDS 8B-8D

Species diversity of grasses and forbs on watershed 8B and 8D was high, resulting in a complex pattern of vegetation. Local areas often had relatively large numbers of species which were less common in similar but removed areas. Consequently, variability within ostensibly similar areas was often as great or greater than variability between areas less similar in appearance. Variation of site characteristics was often subtle and sometimes perhaps only apparent. For these reasons, mapping units are relatively large, and variations within them will be treated descriptively. Transects were placed parallel to the contour because slopes were relatively level and usually not long. Four sites, two communities and one extensive community complex were found on these watersheds (Tables 76-78; Figure 79).

### SHRUB-GRASSLAND--SITE

The Shrub-Grassland site occurred in areas to the north of the main channels of watersheds 8B and 8D, and to the south of the main channel of watershed 8D. These areas were slightly sloping (generally less than 10%) or level. The sandpaper oak-redberry juniper-curlyleaf muhly-Warnock grama community complex (Table 79, Figure 80) was found on this site. Total overstory averaged 7% (0-32%). The vegetation was composed of 64% grasses, 29% forbs and 7% shrubs.

While sandpaper oak (*Quercus pungens*) and redberry juniper (*Juniperus pinchoti*) lent a distinctive aspect to the site as a whole, they were absent from many samples. Also, although on the average, curly-

TABLE 76. SITES AND COMMUNITIES OF WATERSHEDS 8B AND 8D

| Site | Community | Map Symbol |
|---|---|---|
| Shrub-Grassland | Sandpaper oak-redberry juniper-curlyleaf muhly-Warnock grama complex | 26A |
| North Slope Shrubland | Phase of above complex | 27A |
| Grassland Ridge | Blue grama-hairy tridens | 28A |
| Grassland Meadow | Blue grama-black grama | 29A |

TABLE 77. VEGETATIVE COMPOSITION WATERSHED 8D

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| 26A | 78.7 | 272 | .43 |
| 28A | 18.7 | 65 | .10 |
| 29A | 2.6 | 9 | .01 |
|  | 100.0 | 346 | .54 |

TABLE 78. VEGETATIVE COMPOSITION WATERSHED 8B

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| 26A | 60.8 | 58 | .09 |
| 27A | 27.7 | 27 | .04 |
| 28A | 10.0 | 10 | .02 |
| 29A | 11.5 | 1 | < .01 |
|  | 100.0 | 96 | .15 |

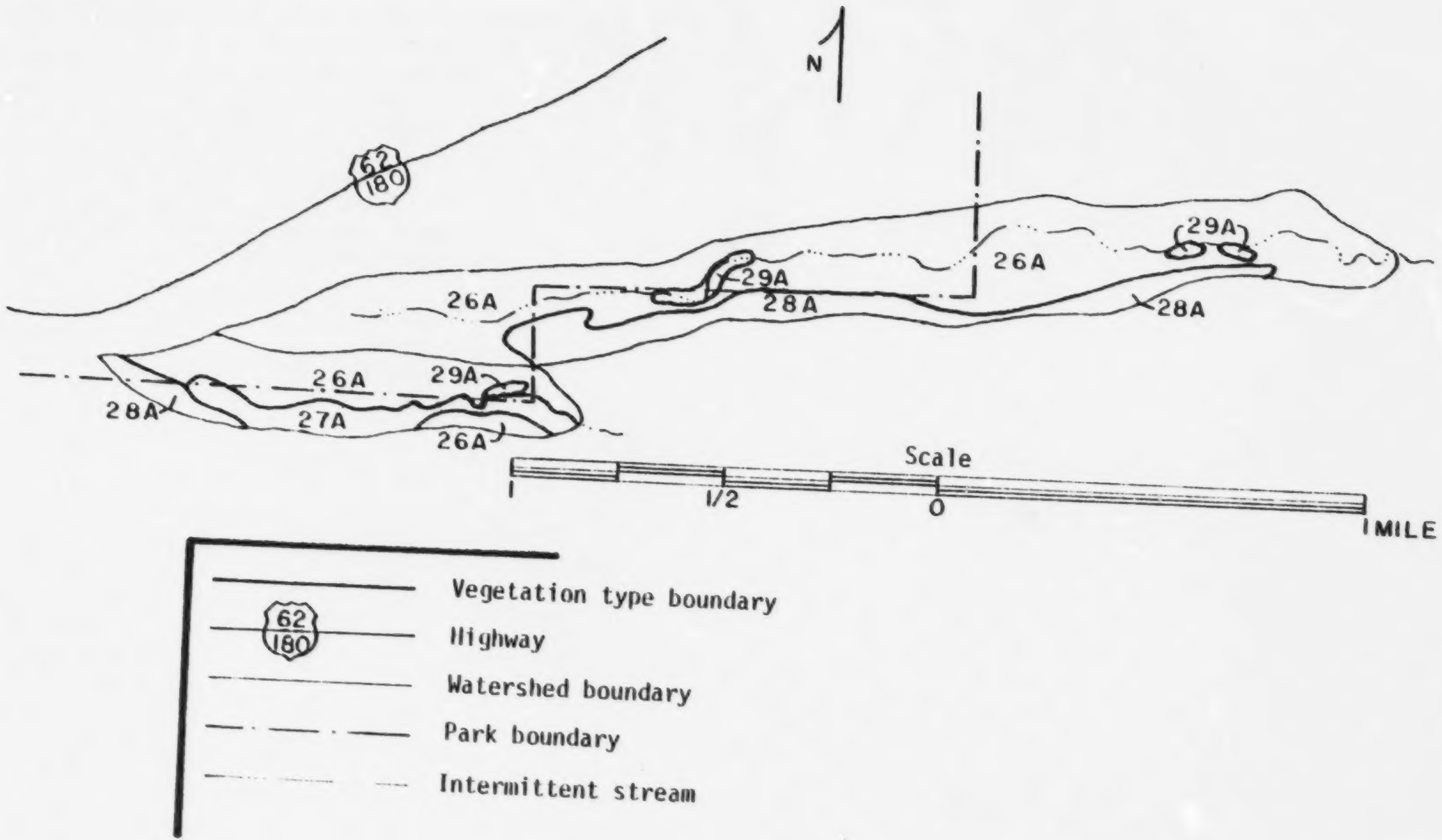

Figure 79. Vegetation Types Watershed 8B-8D.

TABLE 79. SITE CHARACTERISTICS OF THE SHRUB-GRASSLAND SITE AND SPECIES COMPOSITION OF THE SANDPAPER OAK-REDBERRY JUNIPER-CURLYLEAF MUHLY-WARNOCK GRAMA COMMUNITY COMPLEX

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5300 | 5050-5550 | | | | | | | | |
| Slope (%) | 8 | 0-26 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 8 | 4-12 | | | | | | | | |
| Litter | 24 | 12-46 | | | | | | | | |
| Small rock | 49 | 30-74 | | | | | | | | |
| Large rock | 2 | 0-8 | | | | | | | | |
| Bare ground | 15 | 2-20 | | | | | | | | |
| Cryptogam | 2 | 0-12 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 7 | 0-32 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 7 | 0-32 | | | | | | | | |
| Grasses (%) | 64 | 38-76 | | | | | | | | |
| Forbs (%) | 29 | 12-62 | | | | | | | | |
| Shrubs (%) | 7 | 0-28 | | | | | | | | |
| Muhlenbergia setifolia--curlyleaf muhly | | | 12 | 0-32 | | | | | | |
| Bouteloua warnockii--Warnock grama | | | 10 | 2-19 | | | | | | |
| Bouteloua hirsuta--hairy grama | | | 9 | 0-30 | | | | | | |
| Lycurus phleoides--wolftail | | | 6 | 0-22 | | | | | | |
| Tridens muticus--slim tridens | | | 5 | 0-18 | | | | | | |
| Erioneuron pilosum--hairy tridens | | | 4 | 0-14 | | | | | | |
| Quercus pungens--sandpaper oak | | | < 1 | 0-4 | 2 | 0-20 | | | | |
| Juniperus pinchoti--redberry juniper | | | < 1 | 0-4 | 2 | 0-16 | | | | |
| Nolina micrantha--smallseed sacahuista | | | < 1 | 0-4 | < 1 | 0-6 | | | | |
| Xanthocephalum sarothrae--broom snakeweed | | | 4 | 0-26 | < 1 | 0-2 | | | | |

Data based on transects 70-72, 77, 78, 80-83, 106-114, 118-121, 123, 126-131

Aspects: Northern, southern, none (level)

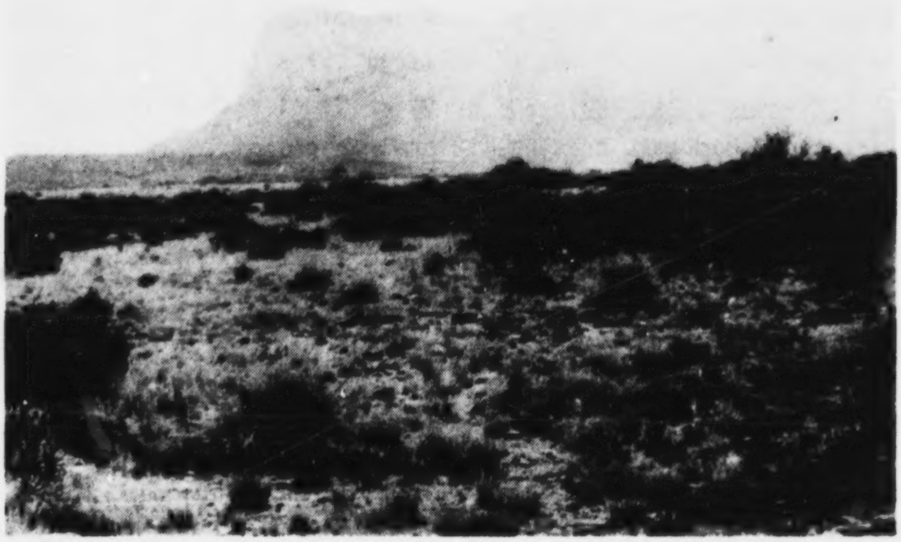

Figure 80. Shrub-Grassland Site; sandpaper oak-redberry juniper-curlyleaf muhly-Warnock grama community complex.

Figure 81. North Slope Shrubland Site; phase of the sandpaper oak-redberry juniper-curlyleaf muhly-Warnock grama community complex.

leaf muhly (12%), Warnock grama (10%) and hairy grama (9%) were the most common grasses, there were areas where they were relatively unimportant. Many grass species occurred, sometimes in relative but local abundance. For the entire site, there was 6% wolftail, 5% slim tridens, 4% hairy tridens (Erioneuron pilosum), and about 2% to 4% each of Aristida spp., blue threeawn, shortleaf tridens (Erioneuron grandiflorum), Hall's panicum (Panicum hallii), New Mexico feathergrass, sand dropseed (Sporobolus cryptandrus), sideoats grama and plains lovegrass. Also, many forbs were present. However, only Lesquerella spp. was usually consistently abundant. Other common species included needleleaf bluets, common and prickleaf dyssodias, Linum spp., narrowleaf milkwort, plains zinnia (Zinnia grandiflora), drummond hedeoma, longstalk greenthread and babywhite-aster, among many others.

In some areas, broom snakeweed (Xanthocephalum sarothrae) was very abundant, constituting up to 26% of the species composition. In these areas, Warnock grama (8%), was common. Wolftail, slim tridens and blue grama were also locally abundant. Curlyleaf muhly was relatively infrequent. In general, few shrubs other than broom snakeweed were present.

In other areas, shrub overstory was relatively high (23%), due primarily to the presence of sandpaper oak, redberry juniper and smallseed sacahuista, which contributed 3% and 11%, 1% and 7%, and 2% and 4%, to the species composition and overstory, respectively. Warnock grama (11%), hairy grama (9%), wolftail (8%) and slim tridens (7%) were the most common grasses. There was 6% curlyleaf muhly and 6% plains lovegrass. These areas, because of the increased overstory, generally had less vegetative ground cover (5%) and small rock (36%), and more litter (34%) than the site as a whole.

One small area had 58% small rock, 18% bare ground and 14% litter. Sixty-two percent of the vegetation was forbs, with 38% grasses and no shrubs. Wolftail (8%), curlyleaf muhly (6%) and hairy grama (6%) were the most common grasses, with smaller amounts of Hall's panicum, Aristida spp., and plains lovegrass. Longstalk greenthread (34%) was locally very abundant, with smaller amounts of needleleaf bluets (16%), Lesquerella spp. (8%) and other species.

Closer to the bottoms of the slopes on the site, near the stream terraces, there was generally more small rock (61%) and less bare ground (6%). Curlyleaf muhly and hairy grama were often the most common grasses, although wolftail, Warnock grama and hairy tridens were also locally abundant.

## NORTH SLOPE SHRUBLAND--SITE

The North Slope Shrubland site occurred on the north-facing exposures south of the main channel of watershed 8B. Site characteristics were somewhat divergent from those of the Shrub-Grassland site. On the North Slope Shrubland site, slopes were steeper (22%). There was more overstory (10%) and litter (40%), and less small rock (37%) and bare ground (11%). Vegetative ground cover, however, was similar (10%). In the species composition, while the shrub component (5%) was similar, there were more grasses (77%) and fewer forbs (18%).

The most common species in the North Slope Shrubland site were sandpaper oak and redberry juniper in the shrub component of the vegetation, and curlyleaf muhly and New Mexico feathergrass in the understory (Table 80, Figure 81). Relative to dominant species, this vegetation is similar to the sandpaper oak-redberry juniper-curlyleaf muhly-Warnock grama community complex of the Shrub-Grassland site (except for New Mexico feathergrass, discussed below). However, greater amounts of sandpaper oak and redberry juniper occurred in the North Slope Shrubland site, both in species composition and overstory (1% and 5%, and 1% and 4%, respectively). Also, although not abundant, skunkbush was relatively frequent in the North Slope Shrubland site, occurring in 50% of the samples. This species occurred in only 14% of the samples in the Shrub-Grassland site. Smallseed sacahuista was also infrequent in the North Slope Shrubland site.

Forbs (18%) made up a smaller proportion of the vegetation in the North Slope Shrubland site than in the Shrub-Grassland site. Although _Lesquerella_ spp. was most common, it occurred in much smaller amounts than in the Shrub-Grassland site. Also, needleleaf bluets and common and prickleaf dyssodias were absent, and _Linum_ spp., drummond hedeoma and longstalk greenthread were infrequent.

TABLE 80. SITE CHARACTERISTICS OF THE NORTH SLOPE SHRUBLAND SITE AND SPECIES COMPOSITION OF A PHASE OF THE SANDPAPER OAK-REDBERRY JUNIPER-CURLYLEAF MUHLY-WARNOCK GRAMA COMMUNITY COMPLEX

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5480 | 5120-5520 | | | | | | | | |
| Slope (%) | 22 | 16-30 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 10 | 6-16 | | | | | | | | |
| Litter | 40 | 28-50 | | | | | | | | |
| Small rock | 37 | 28-48 | | | | | | | | |
| Large rock | 1 | 0-2 | | | | | | | | |
| Bare ground | 11 | 8-14 | | | | | | | | |
| Cryptogam | 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 10 | 4-16 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 10 | 4-16 | | | | | | | | |
| Grasses (%) | 77 | 68-88 | | | | | | | | |
| Forbs (%) | 18 | 8-28 | | | | | | | | |
| Shrubs (%) | 5 | 0-10 | | | | | | | | |
| *Stipa neomexicana*--New Mexico feathergrass | | | 17 | 0-50 | | | | | | |
| *Muhlenbergia setifolia*--curlyleaf muhly | | | 16 | 8-34 | | | | | | |
| *Bouteloua hirsuta*--hairy grama | | | 10 | 0-22 | | | | | | |
| *Bouteloua warnockii*--Warnock grama | | | 7 | 3-11 | | | | | | |
| *Sporobolus cryptandrus*--sand dropseed | | | 6 | 2-12 | | | | | | |
| *Quercus pungens*--sandpaper oak | | | 1 | 0-2 | 5 | 0-14 | | | | |
| *Juniperus pinchoti*--redberry juniper | | | 1 | 0-4 | 4 | 0-10 | | | | |
| *Rhus aromatica*--skunkbush | | | | | < 1 | 0-2 | | | | |

Data based on transects 103-105, 115-117

Aspects: Northern

Thus although the same species are, in general, present and dominant in both the North Slope Shrubland and Shrub-Grassland sites, their relative amounts differ. Also, several differential species (e.g., New Mexico feathergrass and skunkbush) appear between the two sites. Because of the complex nature of the vegetation in these areas, the vegetation of the northern aspects of watershed 8B under discussion is thus considered a phase of the sandpaper oak-redberry juniper-curlyleaf muhly-Warnock grama community complex. A separate site status, however, is assigned because of the differences in site characteristics, and the opinion that these two areas are potentially capable of supporting different vegetation, some indications of which can be seen in this data.

## GRASSLAND RIDGE--SITE

The Grassland Ridge site occurred on the level ridge along the southern boundary of watershed 8D. There was less small rock (36%), slightly less litter (20%), more bare ground (29%) and less overstory (4%) than in the Shrub-Grassland site. Vegetative ground cover (7%) was similar between the two sites. Although the data averages show more shrubs in the species composition of the Grassland Ridge site than in the Shrub-Grassland site, this is due to relatively large amounts of broom snakeweed in one sampling area. Otherwise, shrubs made up only 4% of the species composition.

The blue grama-hairy tridens community (Table 81, Figure 82) was found on the Grassland Ridge site. On the average, blue grama (21%) and hairy tridens (12%) were the most common grasses. However, in one area, wolftail (14%) and plains lovegrass (12%) were also common. Curlyleaf muhly and Warnock grama were generally uncommon.

Broom snakeweed was locally abundant in one area of the site, making up to 24% of the species composition. In this area, hairy tridens (15%) and blue grama (9%) were the most common grasses. Lesquerella spp. was the most common forb.

In other areas of the site, scattered broom snakeweed individuals were the only common shrubs. Blue grama (19%) and wolftail (14%) were the most common grasses, along with 12% plains lovegrass and 9% hairy tridens. Lesquerella spp. and plains blackfoot were the most common forbs.

TABLE 81. SITE CHARACTERISTICS OF THE GRASSLAND RIDGE SITE AND SPECIES COMPOSITION OF THE BLUE GRAMA-HAIRY TRIDENS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5200 | 5080-5400 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 7 | 4-8 | | | | | | | | |
| Litter | 20 | 10-28 | | | | | | | | |
| Small rock | 36 | 26-42 | | | | | | | | |
| Large rock | 6 | 0-24 | | | | | | | | |
| Bare ground | 29 | 0-42 | | | | | | | | |
| Cryptogam | 2 | 0-4 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 4 | 0-10 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 4 | 0-10 | | | | | | | | |
| Grasses (%) | 71 | 48-90 | | | | | | | | |
| Forbs (%) | 16 | 10-28 | | | | | | | | |
| Shrubs (%) | 13 | 0-36 | | | | | | | | |
| *Bouteloua gracilis*--blue grama | | | 21 | 4-40 | | | | | | |
| *Erioneuron pilosum*--hairy tridens | | | 12 | 6-16 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 10 | 0-20 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 8 | 0-18 | | | | | | |
| *Juniperus pinchoti*--redberry juniper | | | 1 | 0-6 | < 1 | 0-4 | | | | |
| *Quercus pungens*--sandpaper oak | | | < 1 | 0-2 | < 1 | 0-4 | | | | |
| *Nolina micrantha*--smallseed sacahuista | | | < 1 | 0-2 | < 1 | 0-2 | | | | |
| *Xanthocephalum sarothrae*--broom snakeweed | | | 10 | 0-24 | | | | | | |

Data based on transects 123, 125, 73-75

Aspects: None (level)

Figure 82. Grassland Ridge Site; blue grama-hairy tridens community.

Figure 83. Grassland Meadow Site; blue grama-black grama community.

## GRASSLAND MEADOW--SITE

Adjacent to the main channels of these watersheds were small inclusions of meadows which constituted the Grassland Meadow site. Litter covered 31% of the ground, with 14% vegetative ground cover, 41% bare ground, 7% small rock and no large rock.

The blue grama-black grama community (Table 82, Figure 83) occurred in the Grassland Meadow site. Broom snakeweed was the only common shrub, and even it was not abundant. Also present were scattered individuals of soaptree yucca (_Yucca elata_) and cholla. Blue grama (43%) and black grama (21%) were common grasses. Hairy grama (7%) was also present, with lesser amounts of _Aristida_ spp. (1%), and vine-mesquite (1%). _Evax_ spp. (9%), wooly Indian wheat (3%) and grassland croton (_Croton dioicus_) (3%) were the forbs most frequently encountered; although a number of other species were present.

## WATERSHED 7

Watershed 7 is made up of sedimentary rock with slopes generally greater than 50%, very sparse mountain shrub vegetation, and denser riparian vegetation along the streams. Nine sites, one inclusion, ten communities and one community complex were found on the watershed (Tables 83, 84; Figure 84).

## STEEP OPEN--SITE

Higher elevation northern, eastern and southern aspects were relatively inaccessible and difficult to sample, as slopes averaged 67%. Although only southern aspects have been sampled, personal reconnaissance and examination of aerial photographs suggest that these aspects are approximately similar, and will be mapped accordingly. These areas constituted the Steep Open site. Small rock (43%) dominated the ground cover. There was also 27% large rock, 20% litter and only 7% vegetative ground cover. The skeleton goldeneye-New Mexico muhly-sideoats grama community (Table 85, Figure 85) was found here. Shrubs composed 31% of the vegetation, and a number of species were important. Skeleton goldeneye (15%) was the dominant shrub with respect to species composition, and also made up 3% of the overstory. However, smooth sotol, evergreen sumac (_Rhus virens_) and wavyleaf oak

TABLE 82. SITE CHARACTERISTICS OF THE GRASSLAND MEADOW SITE AND SPECIES COMPOSITION OF THE BLUE GRAMA-BLACK GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5200 | 5020-5360 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 14 | 8-18 | | | | | | | | |
| Litter | 31 | 24-38 | | | | | | | | |
| Small rock | 7 | 6-10 | | | | | | | | |
| Large rock | 0 | -- | | | | | | | | |
| Bare ground | 41 | 36-48 | | | | | | | | |
| Cryptogam | 7 | 4-12 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 5 | 0-8 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 5 | 0-8 | | | | | | | | |
| Grasses (%) | 75 | 60-84 | | | | | | | | |
| Forbs (%) | 23 | 12-40 | | | | | | | | |
| Shrubs (%) | 2 | 0-4 | | | | | | | | |
| Bouteloua gracilis--blue grama | | | 43 | 34-50 | | | | | | |
| Bouteloua eriopoda--black grama | | | 21 | 6-36 | | | | | | |
| Bouteloua hirsuta--hairy grama | | | 7 | 0-12 | | | | | | |
| Xanthocephalum sarothrae--broom snakeweed | | | 1 | 0-23 | 3 | 0-4 | | | | |
| Opuntia imbricata--cholla | | | < 1 | 0-2 | 1 | 0-4 | | | | |
| Yucca elata--soaptree yucca | | | < 1 | 0-2 | < 1 | 0-2 | | | | |

Data based on transects 76, 79, 122

Aspects: None (level)

## TABLE 83. SITES AND COMMUNITIES OF WATERSHED 7

| Site | Community | Map Symbol |
|---|---|---|
| Steep Open | Skeleton goldeneye-New Mexico muhly-sideoats grama | 30A |
| Higher Elevation Ridgetop (5900 ft.) | *Quercus*-smooth sotol-blue threeawn | Not mapped |
| (Inclusion) | Wavyleaf oak-mountain mahogany-sideoats grama-littleawn needlegrass | 31A |
| Mid Elevation Ridgetop (5400 ft.) | Smooth sotol-sideoats grama-bull muhly | Not mapped |
| Lowest Elevation Ridge (5270 ft.) | Lecheguilla-skeleton goldeneye-curlyleaf muhly | 32A |
| Steep Southern Ridge | *Quercus*-smooth sotol-sideoats grama-littleawn needlegrass | 33A |
| Steep Northeastern Ridge | *Quercus*-smooth sotol-mountain mahogany-littleawn needlegrass complex | 34A |
| Shrub Slope Bench | Gray oak-sideoats grama-plains lovegrass | 35A |
|  | *Quercus*-redberry juniper-plains lovegrass | 35B |
|  | Catclaw mimosa-Engelmann prickly-pear-blue grama | 35C |
| Grassland Bench | Redberry juniper-hairy grama-blue grama | 36A |

## TABLE 84. VEGETATIVE COMPOSITION WATERSHED 7

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| 30A | 21.8 | 234 | .37 |
| 31A | 0.7 | 8 | .01 |
| 32A | 16.6 | 179 | .28 |
| 33A | 5.9 | 64 | .10 |
| 34A | 9.7 | 104 | .16 |
| 35A | 10.6 | 114 | .18 |
| 35B | 16.0 | 172 | .27 |
| 35C | 8.2 | 88 | .14 |
| 40A | 1.6 | 17 | .02 |
| 36A | 8.9 | 96 | .15 |
|  | 100.0 | 1,076 | 1.68 |

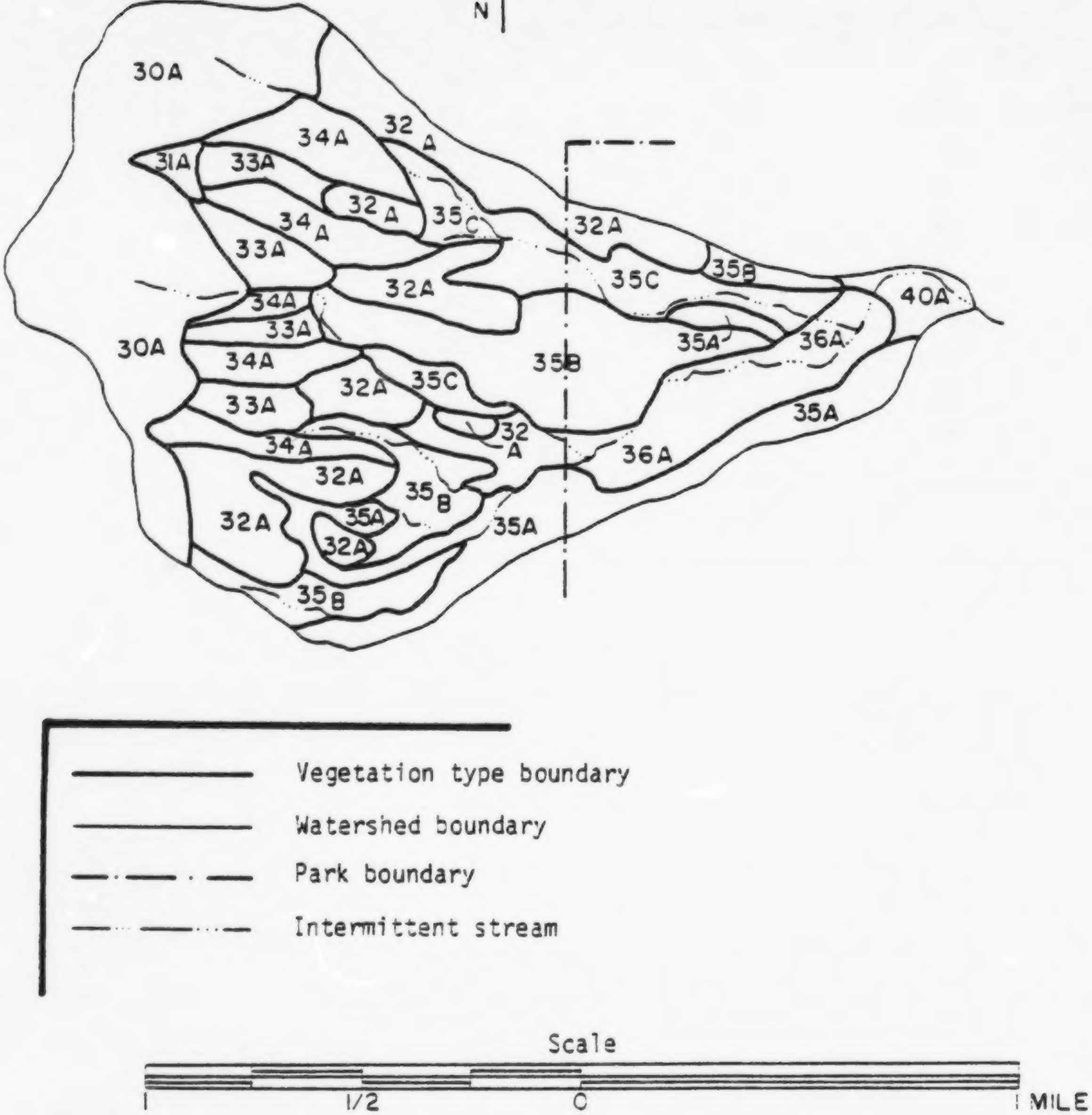

Figure 34. Vegetation Types Watershed 7.

TABLE 85. SITE CHARACTERISTICS OF THE STEEP OPEN SITE AND SPECIES COMPOSITION OF THE SKELETON GOLDENEYE-NEW MEXICO MUHLY-SIDEOATS GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6320 | 5400-7000 | | | | | | | | |
| Slope (%) | 67 | 65-71 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 7 | 4-10 | | | | | | | | |
| Litter | 20 | 8-32 | | | | | | | | |
| Small rock | 43 | 16-68 | | | | | | | | |
| Large rock | 27 | 8-50 | | | | | | | | |
| Bare ground | 3 | 0-8 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 13 | 4-20 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 13 | 4-20 | | | | | | | | |
| Grasses (%) | 57 | 52-66 | | | | | | | | |
| Forbs (%) | 12 | 10-14 | | | | | | | | |
| Shrubs (%) | 31 | 24-38 | | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 15 | 10-24 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 10 | 0-24 | | | | | | |
| *Leptochloa dubia*--green sprangletop | | | 7 | 4-12 | | | | | | |
| *Muhlenbergia setifolia*--curlyleaf muhly | | | 6 | 4-10 | | | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 15 | 12-22 | 3 | 0-6 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 3 | 0-4 | 3 | 0-6 | | | | |
| *Quercus undulata*--wavyleaf oak | | | 2 | 0-4 | 2 | 0-8 | | | | |
| *Rhus virens*--evergreen sumac | | | 4 | 0-12 | 2 | 0-6 | | | | |

Data based on transects 20-22, 24, 25

Aspects: Northern, eastern, southern

Figure 85. Background (center and right): Steep Open Slope; skeleton goldeneye-New Mexico muhly-sideoats grama community.
Foreground: Shrub Slope-Bench Site; Quercus-redberry juniper-plains lovegrass community.

Figure 86. Lowest Elevation Ridge (5270 ft.) Site; lecheguilla-skeleton goldeneye-curlyleaf muhly community.

were also common, with smaller amounts of mountain mahogany, Quercus spp., smallseed sacahuista, mariola parthenium, apacheplume, lecheguilla and Engelmann pricklypear. New Mexico muhly (15%) and sideoats grama (10%) were the most common grasses, although a variety of species were found. Green sprangletop (Leptochloa dubia) (7%) and curlyleaf muhly (6%) were common, with smaller amounts of littleawn needlegrass, bull muhly and slim tridens. Forbs comprised 12% of the vegetation, and a wide variety of species were present, although none were abundant. Galium spp. (2%), noseburn (2%) and white sage (2%) were common, with smaller amounts of Hawkweed wildbuckwheat, Sisymbrium linearifolium, California brickellbush (Brickellia california), gray golden-aster (Heterotheca villosa) and many others.

## HIGHER ELEVATION RIDGETOP (5900 ft.)--SITE

The Higher Elevation Ridgetop (5900 ft.) site differed from mid and lower elevation ridgetops (discussed below), and thus constituted a distinct site. This site was of limited areal extent and is not shown on the vegetation map. A distinguishing feature of this site was the high proportion of large rock (51%) in the ground cover. This site supported the Quercus-smooth sotol-blue threeawn community (Table 86). Total overstory averaged 22%, nearly all of which was composed of Quercus spp. (7%), sandpaper oak (5%), wavyleaf oak (4%) and smooth sotol (4%). All of these species were also important in the species composition of the community, along with 12% lecheguilla and 3% rabbitbrush. Skeleton goldeneye, mountain mahogany and smallseed sacahuista were infrequent or absent. Blue threeawn (17%) and Aristida spp. (9%) were the most common understory species. Also present were littleawn needlegrass (6%) and smaller amounts of Carex spp., curlyleaf muhly, sideoats grama, slim tridens, little bluestem and bull muhly. Forbs made up only 9% of the vegetation. None of the few forbs present, for example, Mexican dogweed (Chrysactinia mexicana) (2%), noseburn (2%), knotweed leafflower (Phyllanthus polygonoides) (1%), among others, were abundant.

A wavyleaf oak-mountain mahogany-sideoats grama-littleawn needlegrass community (Table 87) was found as an inclusion in a pocket of an upper ridge at 6440 ft. Total overstory averaged 27%. Shrubs made up 37% of the vegetation, and a number of species were important. Wavy-

TABLE 86. SITE CHARACTERISTICS OF THE HIGHER ELEVATION RIDGETOP (5900 FT.) SITE AND SPECIES COMPOSITION OF THE QUERCUS-SMOOTH SOTOL-BLUE THREEAWN COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5900 | 5600-7000 | | | | | | | | |
| Slope (%) | 40 | 31-50 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 10 | 6-12 | | | | | | | | |
| Litter | 24 | 18-30 | | | | | | | | |
| Small rock | 16 | 10-20 | | | | | | | | |
| Large rock | 50 | 40-62 | | | | | | | | |
| Bare ground | 0 | -- | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 22 | 12-30 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 22 | 12-30 | | | | | | | | |
| Grasses (%) | 56 | 46-64 | | | | | | | | |
| Forbs (%) | 9 | 6-14 | | | | | | | | |
| Shrubs (%) | 35 | 22-48 | | | | | | | | |
| Aristida glauca--blue threeawn | | | 17 | 6-40 | | | | | | |
| Aristida spp.--threeawn | | | 9 | 2-16 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 6 | 2-8 | | | | | | |
| Carex spp.--sedge | | | 4 | 2-6 | | | | | | |
| Muhlenbergia setifolia--curlyleaf muhly | | | 3 | 0-8 | | | | | | |
| Tridens muticus--slim tridens | | | 2 | 0-4 | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 2 | 0-4 | | | | | | |
| Quercus spp.--oak | | | 2 | 0-4 | 7 | 0-12 | | | | |
| Quercus undulata--wavyleaf oak | | | 4 | 0-8 | 4 | 0-8 | | | | |
| Quercus pungens--sandpaper oak | | | 4 | 0-6 | 5 | 0-12 | | | | |
| Dasylirion leiophyllum--smooth sotol | | | 6 | 0-14 | 4 | 0-8 | | | | |
| Rhus virens--evergreen sumac | | | 2 | 0-4 | 7 | 0-12 | | | | |
| Agave lecheguilla--lecheguilla | | | 12 | 4-18 | | | | | | |

Data based on transects 23, 49, 59, 60

Aspects: Eastern

## TABLE 87. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-MOUNTAIN MAHOGANY-SIDEOATS GRAMA-LITTLEAWN NEEDLEGRASS COMMUNITY INCLUSION

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 6440 | 6400-6600 | | | | | | | | |
| Slope (%) | 50 | 46-53 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 11 | 8-16 | | | | | | | | |
| Litter | 33 | 20-56 | | | | | | | | |
| Small rock | 30 | 24-56 | | | | | | | | |
| Large rock | 22 | 0-36 | | | | | | | | |
| Bare ground | 4 | 0-10 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 27 | 12-54 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 27 | 12-54 | | | | | | | | |
| Grasses (%) | 53 | 48-58 | | | | | | | | |
| Forbs (%) | 10 | 4-12 | | | | | | | | |
| Shrubs (%) | 37 | 32-48 | | | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 16 | 6-38 | | | | | | |
| Stipa lobata--littleawn needlegrass | | | 15 | 4-22 | | | | | | |
| Muhlenbergia pauciflora--New Mexico muhly | | | 6 | 2-12 | | | | | | |
| Aristida glauca--blue threeawn | | | 4 | 0-14 | | | | | | |
| Leptochloa dubia--green sprangletop | | | 3 | 0-12 | | | | | | |
| Quercus undulata--wavyleaf oak | | | 7 | 0-28 | 12 | 0-48 | | | | |
| Quercus spp.--oak | | | 3 | 0-10 | 2 | 0-8 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 7 | 0-2 | 6 | 0-14 | | | | |
| Dasylirion leiophyllum--smooth sotol | | | 4 | 0-8 | 3 | 0-6 | | | | |
| Nolina micrantha--sacahuista | | | 2 | 0-4 | 2 | 0-4 | | | | |

Data based on transects 26-30

Aspects: Northeast to eastern

leaf oak and Quercus spp. were the most common shrubs, accounting for 10% of the species composition and 15% of the overstory. Smooth sotol and mountain mahogany contributed 4% and 3%, and 7% and 6%, to the species composition and overstory, respectively. Smallseed sacahuista also occurred. Lecheguilla (8%) and skeleton goldeneye (4%) were common, along with smaller amounts of tatalencho. Grasses made up 53% of the vegetation. Sideoats grama (16%) and littleawn needlegrass (15%) were the dominant understory species. New Mexico muhly (6%) was also common. Other species included blue threeawn (4%), green sprangletop (3%), and 1% to 2% each of pine muhly, slim tridens and Carex spp. Many forbs were present, but none were common or abundant. Species included Galium spp., wavyleaf thistle (Cirsium undulatum), Hawkweed wildbuckwheat, Euphorbia spp., plains fleabane and plains blackfoot, among many others.

## MID-ELEVATION RIDGETOP (5440 ft.)--SITE

The Mid Elevation Ridgetop (5440 ft.) site constituted a separate site from the Higher Elevation Ridgetop (5900 ft.) site. This site was also too small to delineate on the map. It had much less large rock (20%), and much more small rock (38%). Slopes were also much more moderate (31%). While vegetative ground cover was very similar (9%), the Mid Elevation Ridgetop (5440 ft.) site had only about half as much overstory (11%). Forbs (5%) made up a smaller proportion of the vegetation. The smooth sotol-sideoats grama-bull muhly community (Table 88) occurred on this site. Quercus spp. was much less important in this community. Only wavyleaf oak was found, accounting for 1% of the species composition and 3% of the overstory. Smooth sotol and skeleton goldeneye dominated and shrub composition, each contributing 6%. Lecheguilla accounted for an additional 10%, and in this respect only, were the Quercus-smooth sotol-blue threeawn and smooth sotol-sideoats grama-bull muhly communities similar. Sideoats grama (15%) and bull muhly (11%) were the dominant understory species with slim tridens (9%) and curlyleaf muhly (9%) common. Many species, for example hairy grama, wolftail, sand dropseed, green sprangletop and black grama occurred in amounts ranging from 1% to 3%. Blue threeawn, Aristida spp., littleawn needlegrass and Carex spp. were infrequent or absent,

TABLE 88. SITE CHARACTERISTICS OF THE MID ELEVATION RIDGETOP (5440 FT.) SITE AND SPECIES COMPOSITION OF THE SMOOTH SOTOL-SIDEOATS GRAMA-BULL MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5440 | 5300-5600 | | | | | | | | |
| Slope (%) | 31 | 29-32 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 9 | 6-14 | | | | | | | | |
| Litter | 30 | 24-32 | | | | | | | | |
| Small rock | 38 | 36-42 | | | | | | | | |
| Large rock | 20 | 16-22 | | | | | | | | |
| Bare ground | 3 | 0-6 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 11 | 2-18 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 11 | 2-18 | | | | | | | | |
| Grasses (%) | 59 | 36-78 | | | | | | | | |
| Forbs (%) | 5 | 0-10 | | | | | | | | |
| Shrubs (%) | 36 | 22-54 | | | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 15 | 4-30 | | | | | | |
| *Muhlenbergia emersleyi*--bull muhly | | | 11 | 8-14 | | | | | | |
| *Muhlenbergia setifolia*--curlyleaf muhly | | | 9 | 6-14 | | | | | | |
| *Tridens muticus*--slim tridens | | | 9 | 6-18 | | | | | | |
| *Bouteloua hirsuta*--hairy grama | | | 3 | 0-8 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 3 | 0-6 | | | | | | |
| *Sporobolus cryptandrus*--sand dropseed | | | 3 | 0-4 | | | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 6 | 4-12 | 2 | 0-10 | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 6 | 0-10 | 1 | 0-2 | | | | |
| *Quercus undulata*--wavyleaf oak | | | 1 | 0-4 | 3 | 0-12 | | | | |
| *Agave lecheguilla*--lecheguilla | | | 10 | 6-26 | | | | | | |

Data based on transects 64-67

Aspects: Eastern

also distinguishing the Quercus-smooth sotol-blue threeawn and smooth sotol-sideoats grama-bull muhly communities. Few forbs were present, and none were abundant.

## LOWEST ELEVATION RIDGE (5270 ft.)--SITE

The Lowest Elevation Ridge (5270 ft.) site was different from the Higher Elevation Ridgetop (5900 ft.) and Mid Elevation Ridgetop (5440 ft.) sites. However, it was more similar to the Mid Elevation Ridgetop (5440 ft.) than the Higher Elevation Ridgetop (5900 ft.) site. This site occurred on the tops of the lower elevation ridges and on their southern exposures. While vegetative ground cover (9%) was very similar to the Higher Elevation Ridgetop (5900 ft.) and Mid Elevation Ridgetop (5440 ft.) sites, and although overstory decreased to 5%, there was more litter (38%). This site also supported different vegetation, the lecheguilla-skeleton goldeneye-curlyleaf muhly community (Table 89, Figure 86).

Vegetation on the tops and sides of these ridges was somewhat different. On the ridgetops, lecheguilla (23%) dominated the shrub composition. Smooth sotol was the most important overstory species, contributing 2%, but was infrequent in the species composition (1%). Silver dalea (Dalea argyraea) was also common, with 2% in the species composition and 1% in the overstory. Skeleton goldeneye (4%) and Engelmann pricklypear (4%) was common in the species composition but absent from the overstory. Curlyleaf muhly (27%) was the most important understory species. Plains lovegrass (10%) and sideoats grama (8%) were also common, with smaller amounts of bull muhly (5%), wolftail (4%), black grama (3%) and hairy grama (2%). Forbs made up only 2% of the vegetation.

Vegetation on the southern aspects of these ridges was related. However, there was slightly more overstory (6%) and forbs (6%). Lecheguilla (21%) was very similar on the tops and sides of the ridges. On the sides, there was more smooth sotol in the species composition (2%) and more skeleton goldeneye in the overstory (3%). Also, there was less silver dalea (1% in the species composition and 0% in the overstory). In most other respects, the shrub component of the vegetation was very similar. In the understory, curlyleaf muhly (18%),

TABLE 89. SITE CHARACTERISTICS OF THE LOWEST ELEVATION RIDGE (5270 FT.) SITE AND SPECIES COMPOSITION OF THE LECHEGUILLA-SKELETON GOLDENEYE-CURLYLEAF MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5270 | 5000-6000 | | | | | | | | |
| Slope (%) | 19 | 8-29 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 9 | 4-16 | | | | | | | | |
| Litter | 38 | 26-50 | | | | | | | | |
| Small rock | 28 | 12-48 | | | | | | | | |
| Large rock | 16 | 2-26 | | | | | | | | |
| Bare ground | 9 | 0-16 | | | | | | | | |
| Cryptogam | < 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 5 | 0-14 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 5 | 0-14 | | | | | | | | |
| Grasses (%) | 63 | 44-80 | | | | | | | | |
| Forbs (%) | 4 | 2-8 | | | | | | | | |
| Shrubs (%) | 33 | 18-50 | | | | | | | | |
| *Muhlenbergia setifolia*--curlyleaf muhly | | | 22 | 8-46 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 9 | 4-16 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 8 | 4-16 | | | | | | |
| *Bouteloua eriopoda*--black grama | | | 7 | 0-16 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 6 | 0-16 | | | | | | |
| *Tridens muticus*--slim tridens | | | 4 | 0-6 | | | | | | |
| *Agave lecheguilla*--lecheguilla | | | 22 | 2-42 | < 1 | 0-4 | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 4 | 0-14 | 2 | 0-4 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 1 | 0-10 | 2 | 0-10 | | | | |
| *Opuntia engelmannii*--Engelmann pricklypear | | | 4 | 0-6 | | | | | | |
| *Dalea argyraea*--silver dalea | | | 2 | 0-4 | < 1 | 0-2 | | | | |

Data based on transects 32-41, 62, 63

Aspects: None to southern

sideoats grama (8%) and plains lovegrass (8%) were still common, as on the tops of the ridges. However, there was more wolftail (7%), black grama (9%) and slim tridens (6%), and no bull muhly on the sides of the ridges. Plains fleabane (3%) was the most common forb.

## STEEP SOUTHERN RIDGE--SITE

Southern aspects at 5680-5800 ft. constituted the Steep Southern Ridge site. While site characteristics, other than topography, were similar to the Higher Elevation Ridgetop (5900 ft.) site, the vegetation was different. This site supported the _Quercus_-smooth sotol-sideoats grama-littleawn needlegrass community (Table 90, Figure 87). Insofar as the presence of _Quercus_ spp., smooth sotol and lecheguilla is concerned, this community is very similar to the _Quercus_-smooth sotol-blue threeawn community of the Higher Elevation Ridgetop (5900 ft.) site. However, the _Quercus_-smooth sotol-sideoats grama-littleawn needlegrass community generally had less _Quercus_ spp., both in the species composition and overstory. It also had more silver dalea, skeleton goldeneye and evergreen sumac. Important differences in the understory provide more convincing evidence of the separate identity of the two communities. The _Quercus_-smooth sotol-sideoats grama-littleawn needlegrass community had much less _Aristida_ spp. (4%) and blue threeawn (2%), in contrast to the _Quercus_-smooth sotol-blue threeawn community. Littleawn needlegrass (8%) and sideoats grama (8%) were the most common grasses in the _Quercus_-smooth sotol-sideoats grama-littleawn needlegrass community; these species were less important in the _Quercus_-smooth sotol-blue threeawn community. Bull muhly was also locally important in the _Quercus_-smooth sotol-sideoats grama-littleawn needlegrass community, but was uncommon in the _Quercus_-smooth sotol-blue threeawn community. The proportion of forbs in the two communities was similar, and in neither community were any of the species abundant. However, the composition was generally different. _Galium_ spp. (2%), California brickellbush (1%) and white sage (1%) were the most common forbs in the _Quercus_-smooth sotol-sideoats grama-littleawn needlegrass community.

TABLE 90. SITE CHARACTERISTICS OF THE STEEP SOUTHERN RIDGE SITE AND SPECIES COMPOSITION OF THE *QUERCUS*-SMOOTH SOTOL-SIDEOATS GRAMA-LITTLEAWN NEEDLEGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5740 | 5400-6200 | | | | | | | | |
| Slope (%) | 54 | 47-66 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 8 | 6-10 | | | | | | | | |
| Litter | 29 | 16-42 | | | | | | | | |
| Small rock | 19 | 8-36 | | | | | | | | |
| Large rock | 43 | 24-60 | | | | | | | | |
| Bare ground | 1 | 0-4 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 17 | 12-32 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 17 | 12-32 | | | | | | | | |
| Grasses (%) | 52 | 30-66 | | | | | | | | |
| Forbs (%) | 11 | 6-18 | | | | | | | | |
| Shrubs (%) | 37 | 24-64 | | | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 8 | 4-14 | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 8 | 2-18 | | | | | | |
| *Muhlenbergia emersleyi*--bull muhly | | | 5 | 0-20 | | | | | | |
| *Muhlenbergia setifolia*--curlyleaf muhly | | | 5 | 0-22 | | | | | | |
| *Aristida* spp.--threeawn | | | 4 | 2-8 | | | | | | |
| *Aristida glauca*--blue threeawn | | | 2 | 0-6 | | | | | | |
| *Quercus pungens*--sandpaper oak | | | 4 | 0-12 | 4 | 0-10 | | | | |
| *Quercus undulata*--wavyleaf oak | | | 2 | 0-8 | 3 | 0-8 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 6 | 0-16 | 4 | 0-10 | | | | |
| *Rhus virens*--evergreen sumac | | | 4 | 0-8 | 3 | 0-6 | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 3 | 0-6 | 2 | 0-6 | | | | |
| *Agave lecheguilla*--lecheguilla | | | 12 | 8-24 | | | | | | |

Data based on transects 42-44, 55, 56, 58

Aspects: Southern

Figure 87. Steep Southern Ridge Site; Quercus-smooth sotol-sideoats grama-littleawn needlegrass community.

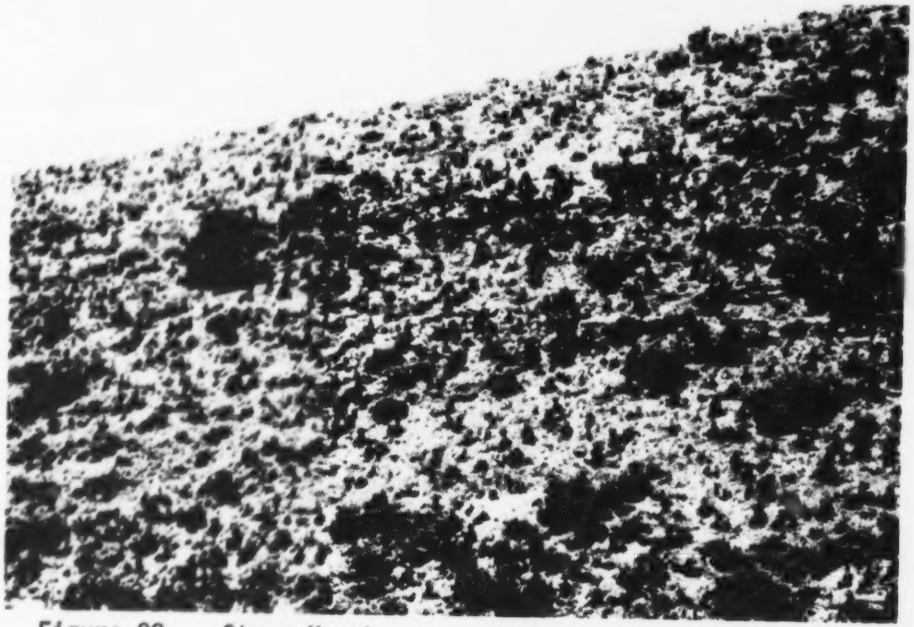

Figure 88. Steep Northeastern Ridge Site; Quercus-smooth sotol-mountain mahogany-littleawn needlegrass community complex.

## STEEP NORTHEASTERN RIDGE--SITE

Steep (56%) northeastern aspects at 5660-6250 ft. constituted the Steep Northeastern Ridge site. This site had more overstory (27%), small rock (29%) and a larger proportion of forbs (21%) than the Steep Southern Ridge site. There was also less large rock (32%). However, amounts of litter and vegetative ground cover were similar between the two sites.

This site was somewhat variable in the vegetation it supported, and the _Quercus_-smooth sotol-mountain mahogany-littleawn needlegrass community complex (Table 91, Figure 88) was designated for mapping purposes.

At the lower elevations (5680 ft.), shrubs comprised 33% of the vegetation, and total overstory averaged 17%. Both smooth sotol and _Quercus_ spp. were important. Smooth sotol contributed 7% to the species composition and 6% to the overstory, wavyleaf oak contributed 4% and 0%, respectively, sandpaper oak contributed 1% and 1%, and gray oak contributed 1% and 4%. Skeleton goldeneye (5%) was also important in the species composition, but was absent from the overstory. Mountain mahogany (7% in the species composition and 1% in the overstory) was also common. In addition, rabbitbrush, Engelmann pricklypear, catclaw mimosa (_Mimosa_ _biuncifera_) and tatalencho were present. Grasses composed 44% of the vegetation. New Mexico muhly (7%), plains lovegrass (5%) and sideoats grama (5%) were the most common species, with smaller amounts of littleawn needlegrass (4%), pine muhly (3%) and curlyleaf muhly (3%). Blue threeawn and _Aristida_ spp. were infrequent or absent. Forbs made up 23% of the vegetation. Plains fleabane (16%) was the most common species, with smaller amounts of _Galium_ spp. (2%), _Euphorbia_ spp. (1%) and knotweed leafflower (1%). This vegetation differed from the _Quercus_-smooth sotol-blue threeawn community of the Higher Elevation Ridgetop (5900 ft.) site in the shrub component because it had more smooth sotol and mountain mahogany, and less _Quercus_ spp., evergreen sumac and lecheguilla. In the understory, sideoats grama, New Mexico muhly and plains lovegrass were more common, and blue threeawn and _Aristida_ spp. were less common. Forbs also made up a larger proportion of the vegetation.

TABLE 91. SITE CHARACTERISTICS OF THE STEEP NORTHEASTERN RIDGE SITE AND SPECIES COMPOSITION OF THE *QUERCUS*-SMOOTH SOTOL-MOUNTAIN MAHOGANY-LITTLEAWN NEEDLEGRASS COMMUNITY COMPLEX

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5380 | 5000-6200 | | | | | | | | |
| Slope (%) | 56 | 52-60 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 7 | 4-10 | | | | | | | | |
| Litter | 30 | 22-48 | | | | | | | | |
| Small rock | 29 | 14-46 | | | | | | | | |
| Large rock | 32 | 18-48 | | | | | | | | |
| Bare ground | 2 | 0-6 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 27 | 14-40 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 27 | 14-40 | | | | | | | | |
| Grasses (%) | 41 | 28-50 | | | | | | | | |
| Forbs (%) | 21 | 2-36 | | | | | | | | |
| Shrubs (%) | 38 | 24-60 | | | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 9 | 0-18 | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 6 | 0-12 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 6 | 2-10 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 4 | 0-8 | | | | | | |
| *Leptochloa dubia*--green sprangletop | | | 3 | 0-16 | | | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 6 | 0-10 | 7 | 2-14 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 6 | 0-16 | 4 | 0-8 | | | | |
| *Quercus undulata*--wavyleaf oak | | | 4 | 0-6 | 4 | 0-14 | | | | |
| *Quercus pungens*--sandpaper oak | | | 2 | 0-6 | 3 | 0-8 | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 6 | 0-20 | < 1 | 0-4 | | | | |

Data based on transects 31, 47, 48, 50, 51, 54, 57, 61

Aspects: Northeastern

In other areas at similar elevations (5800 ft.), skeleton goldeneye (13%) and lecheguilla (10%) were locally common in the species composition. Sandpaper oak and wavyleaf oak were more common, and gray oak less common. Littleawn needlegrass (16%), green sprangletop (8%) and sideoats grama (7%) were the most common grasses, with smaller amounts of blue threeawn (3%), plains lovegrass (3%), sand dropseed (2%) and New Mexico muhly (2%).

At the highest elevations (6140 ft.) of the site, there was less smooth sotol, and more mountain mahogany, smallseed sacahuista, tatalencho and Quercus spp., although the proportion of shrubs in the vegetation remained approximately similar. Total overstory increased to 37%. Littleawn needlegrass (10%), New Mexico muhly (9%) and sideoats grama (6%) remained important, with smaller amounts of pine muhly (3%), plains lovegrass (3%) and green sprangletop (3%). Twenty-five percent of the vegetation was composed of forbs, the most common of which were Galium spp. (7%), hedeoma (3%) and plains fleabane (3%).

## SHRUB SLOPE BENCH--SITE

The Shrub Slope Bench site (Table 92) was found throughout the lower regions of Watershed 7. Topographically, the site occurred on the northwestern, northern and southeastern aspects of ridges at elevations ranging from 5000-5600 ft. with slopes up to 27%; on the tops of these ridges; and on some level areas adjacent to these ridges. Litter covered 45% of the ground, with 28% small rock, 16% bare ground and 6% vegetative ground cover. Overstory totaled 20%.

Along the northwestern to northern sides of the ridges, slopes and overstory averaged 19% and 25%, respectively. The gray oak-sideoats grama-plains lovegrass community (Table 93, Figure 89) was found in these areas. Gray oak was the dominant shrub, accounting for 7% overstory at the 0-6 ft. level and 1% at the 6-20 ft. level. However, redberry juniper, Quercus spp. and skunkbush were also important, along with cholla and rabbitbrush. Sideoats grama (12%) and plains lovegrass (11%) were the most common grasses. Also present were hairy grama (8%), slim tridens (8%) and wolftail (6%), with smaller amounts of a variety of other species. Plains fleabane (4%), needleleaf bluets (3%) and baby-white aster (3%) were the most common forbs, with smaller amounts

TABLE 92. SITE CHARACTERISTICS OF THE SHRUB SLOPE BENCH SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 5180 | 5000-5600 |
| Slope (%) | 17 | 0-27 |
| Ground Cover (%) | | |
| Vegetation | 6 | 2-14 |
| Litter | 45 | 30-62 |
| Small rock | 28 | 0-48 |
| Large rock | 5 | 0-26 |
| Bare ground | 16 | 2-34 |
| Cryptogam | < 1 | 0-2 |
| Overstory (%) | | |
| 0-6' | 19 | 2-32 |
| 6-20' | < 1 | 0-8 |
| > 20' | 0 | -- |
| Total | 20 | 2-38 |
| Grasses (%) | 69 | 54-78 |
| Forbs (%) | 16 | 2-30 |
| Shrubs (%) | 15 | 4-22 |

Data based on transects 52, 53, 132-145

Aspects: None, northwestern, southeastern

### TABLE 93. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE GRAY OAK-SIDEOATS GRAMA-PLAINS LOVEGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5200 | 5000-5600 | | | | | | | | |
| Slope (%) | 19 | 14-27 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 5 | 2-8 | | | | | | | | |
| Litter | 45 | 34-62 | | | | | | | | |
| Small rock | 36 | 22-44 | | | | | | | | |
| Large rock | 4 | 0-14 | | | | | | | | |
| Bare ground | 10 | 2-22 | | | | | | | | |
| Cryptogam | < 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 24 | 14-30 | | | | | | | | |
| 6-20' | 1 | 0-8 | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 25 | 14-38 | | | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 12 | 0-26 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 11 | 4-16 | | | | | | |
| *Bouteloua hirsuta*--hairy grama | | | 8 | 0-24 | | | | | | |
| *Tridens muticus*--slim tridens | | | 8 | 2-14 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 6 | 0-16 | | | | | | |
| *Quercus grisea*--gray oak | | | 2 | 0-4 | 7 | 0-16 | 1 | 0-6 | | |
| *Juniperus pinchoti*--redberry juniper | | | 1 | 0-2 | 4 | 0-14 | | | | |
| *Quercus* spp.--oak | | | 1 | 0-6 | 3 | 0-10 | | | | |
| *Rhus aromatica*--skunkbush | | | 1 | 0-4 | 3 | 0-4 | | | | |
| *Opuntia engelmannii*--Engelmann pricklypear | | | 3 | 0-8 | | | | | | |
| *Chrysothamnus spathulatus*--rabbitbrush | | | 5 | 0-8 | < 1 | 0-2 | | | | |

Data based on transects 132-139, 144, 145

Aspects: Northwestern, northern

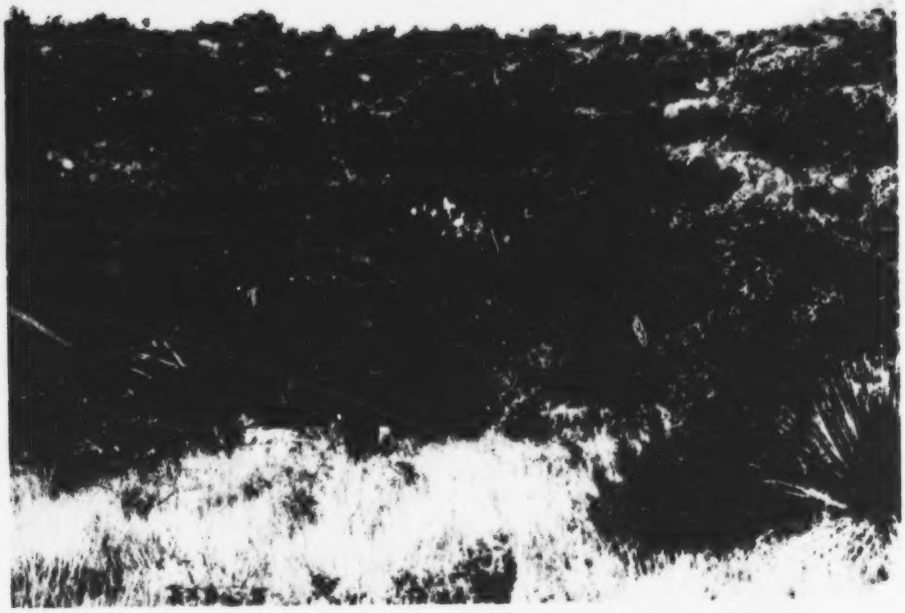

Figure 89. Shrub Slope Bench Site; gray oak-sideoats grama-plains lovegrass.

Figure 90. Shrub Slope Bench Site; catclaw mimosa-Engelmann pricklypear-blue grama.

of perennial verbena (Verbena perennis), knotweed leafflower, narrowleaf milkwort and Euphorbia spp.

Along the tops of these ridges, there was generally less litter, small rock and overstory, and more large rock and bare ground. A community closely related to the gray oak-sideoats grama-plains lovegrass community was found here, the Quercus-redberry juniper-plains lovegrass community (Table 94, Figure 85). Gray oak was infrequent. Quercus spp. and redberry juniper were the most important overstory species, each contributing 6%. Engelmann pricklypear (8%), skeleton goldeneye (3%) and catclaw mimosa (1%) were common in the species composition. Plains lovegrass (18%) was the dominant understory species. Wolftail (11%) and sideoats grama (10%) were also common, with smaller amounts of a variety of species. Baby-white aster (5%), plains fleabane (3%) and Euphorbia spp. (3%) were the most common forbs. Forb and shrub diversity in this community was much lower than in the gray oak-sideoats grama-plains lovegrass community.

In many of the level areas of the site, and often adjacent to the stream channels, the catclaw mimosa-Engelmann pricklypear-blue grama community (Table 95, Figure 90) was found. These areas had much more vegetative ground cover (12%) and bare ground (28%) than the site as a whole, and less small rock (11%) and large rock (1%). However, amount of litter (49%) was similar. Catclaw mimosa, with 2% in both the species composition and overstory, lent a distinctive aspect to the community. Engelmann pricklypear was an important shrub, contributing 8% to the species composition and 3% to the overstory. Blue grama (24%) was the most common understory species. Arizona cottontop (Trichachne californica) was common in some areas, although in other areas it was less common. Cane bluestem (Bothriochloa barbinodis), plains lovegrass and hairy grama, each at 5%, and New Mexico feathergrass (4%) were also common. Plains fleabane, Evax spp. and Chamaesaracha spp. were common forbs, with smaller amounts of wooly Indian wheat and babywhite-aster.

## GRASSLAND BENCH--SITE

The Grassland Bench site was also found on level areas of lower Watershed 7. The site was characterized by 55% bare ground, 30%

TABLE 94. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE *QUERCUS*-REDBERRY JUNIPER-PLAINS LOVEGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5130 | 5000-5600 | | | | | | | | |
| Slope (%) | 11 | 6-15 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 4 | 2-6 | | | | | | | | |
| Litter | 39 | 30-52 | | | | | | | | |
| Small rock | 24 | 10-48 | | | | | | | | |
| Large rock | 14 | 2-26 | | | | | | | | |
| Bare ground | 19 | 14-26 | | | | | | | | |
| Cryptogam | < 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 16 | 2-32 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 16 | 2-32 | | | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 18 | 14-26 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 11 | 6-18 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 10 | 6-12 | | | | | | |
| *Leptoloma cognatum*--fall witchgrass | | | 4 | 0-12 | | | | | | |
| *Bouteloua hirsuta*--hairy grama | | | 4 | 0-10 | | | | | | |
| *Quercus* spp.--oak | | | 2 | 0-4 | 6 | 0-22 | | | | |
| *Juniperus pinchoti*--redberry juniper | | | 1 | 0-2 | 6 | 0-14 | | | | |
| *Opuntia engelmannii*--Engelmann pricklypear | | | 8 | 4-12 | | | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 3 | 0-6 | 1 | 0-4 | | | | |
| *Mimosa biuncifera*--catclaw mimosa | | | 1 | 0-2 | 2 | 2-4 | | | | |

Data based on transects 140-143

Aspects: Eastern

## TABLE 95. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE CATCLAW MIMOSA-ENGELMANN PRICKLYPEAR-BLUE GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5190 | 4900-5200 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 12 | 10-14 | | | | | | | | |
| Litter | 49 | 36-60 | | | | | | | | |
| Small rock | 11 | 0-28 | | | | | | | | |
| Large rock | < 1 | 0-2 | | | | | | | | |
| Bare ground | 28 | 22-34 | | | | | | | | |
| Cryptogam | < 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 10 | 6-14 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 10 | 6-14 | | | | | | | | |
| *Bouteloua gracilis*--blue grama | | | 24 | 14-32 | | | | | | |
| *Trichachne californica*--Arizona cottontop | | | 11 | 2-20 | | | | | | |
| *Bothriochloa barbinodis*--silver bluestem | | | 5 | 0-10 | | | | | | |
| *Bouteloua hirsuta*--hairy grama | | | 5 | 0-16 | | | | | | |
| *Eragrostis lugens*--plains lovegrass | | | 5 | 0-8 | | | | | | |
| *Stipa neomexicana*--New Mexico feathergrass | | | 4 | 0-10 | | | | | | |
| *Mimosa biuncifera*--catclaw mimosa | | | 2 | 0-4 | 2 | 2 | | | | |
| *Opuntia engelmannii*--Engelmann pricklypear | | | 8 | 0-18 | 3 | 0-8 | | | | |
| *Viguiera stenoloba*--skeleton goldeneye | | | 1 | 0-2 | 2 | 0-8 | | | | |
| *Juniperus pinchoti*--redberry juniper | | | | | 2 | 0-4 | | | | |

Data based on transects 52, 53, 68, 69

Aspects: None

litter and 9% vegetative ground cover. This site supported a redberry juniper-hairy grama-blue grama community (Table 96, Figure 91). Hairy grama and blue grama accounted for 25% and 17%, respectively, of the vegetation. Wolftail (6%) and Aristida spp. (5%) were also common, along with smaller amounts of fall witchgrass, sideoats grama, vine-mesquite, plains lovegrass, black grama, sand dropseed, slim tridens, shortleaf tridens and blue threeawn. Grassland croton (7%) was the most common forb. Other species included plains fleabane (4%), Machaeranthera scabrella (3%) and Linum spp., wooly Indian wheat and needleleaf bluets, each at 2%. Even though only 4% of the vegetation was composed of shrubs, there was a number of species in the community. Redberry juniper was the most common, with smaller amounts of broom snakeweed, soaptree yucca, cholla and skunkbush. In some areas, small rock ground cover increased to 50%, with a decrease in litter (14%), bare ground (22%) and overstory (0%). While blue grama (24%) and hairy grama (12%) were still the most abundant grasses, Aristida spp. (8%) and sideoats grama (8%) were also common.

## WATERSHED 6

Time and manpower constraints as well as areal extent prohibited the same level of intensive sampling in Watershed 6 as in the other watersheds. We were fortunate to have access to Bunting's (1978) work to supplement our limited data. While Bunting did not map vegetation, many comparisons between his community designations and ours in this and other watersheds show that his descriptions of vegetation and ours were similar. Since he also covered many areas we were unable to sample, we believe that with a combination of Bunting's (1978) data and ours, together with soil information and careful aerial photographic interpretation, we have a reasonably sound basis for mapping Watershed 6.

Eight sites occurred on Watershed 6. Because data collected in Watersheds 1 and 7 were used to map similar areas in Watershed 6, five sites had been previously characterized in these other watersheds. Along with these sites, three additional sites, one inclusion and thirteen communities were identified (Tables 97, 98; Figure 93).

TABLE 96. SITE CHARACTERISTICS OF THE GRASSLAND BENCH SITE AND SPECIES COMPOSITION OF THE REDBERRY JUNIPER-HAIRY GRAMA-BLUE GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5140 | 4900-5200 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 9 | 8-10 | | | | | | | | |
| Litter | 30 | 24-36 | | | | | | | | |
| Small rock | 5 | 4-6 | | | | | | | | |
| Large rock | 0 | -- | | | | | | | | |
| Bare ground | 55 | 48-62 | | | | | | | | |
| Cryptogam | 1 | 0-2 | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 7 | 0-18 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 7 | 0-18 | | | | | | | | |
| Grasses (%) | 72 | 60-84 | | | | | | | | |
| Forbs (%) | 24 | 14-30 | | | | | | | | |
| Shrubs (%) | 4 | 0-10 | | | | | | | | |
| *Bouteloua hirsuta*--hairy grama | | | 25 | 12-48 | | | | | | |
| *Bouteloua gracilis*--blue grama | | | 17 | 14-24 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 6 | 4-10 | | | | | | |
| *Aristida* spp.--threeawn | | | 5 | 0-8 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 3 | 0-8 | | | | | | |
| *Leptoloma cognatum*--fall witchgrass | | | 3 | 0-8 | | | | | | |

Data based on transects 146-148

Aspects: None

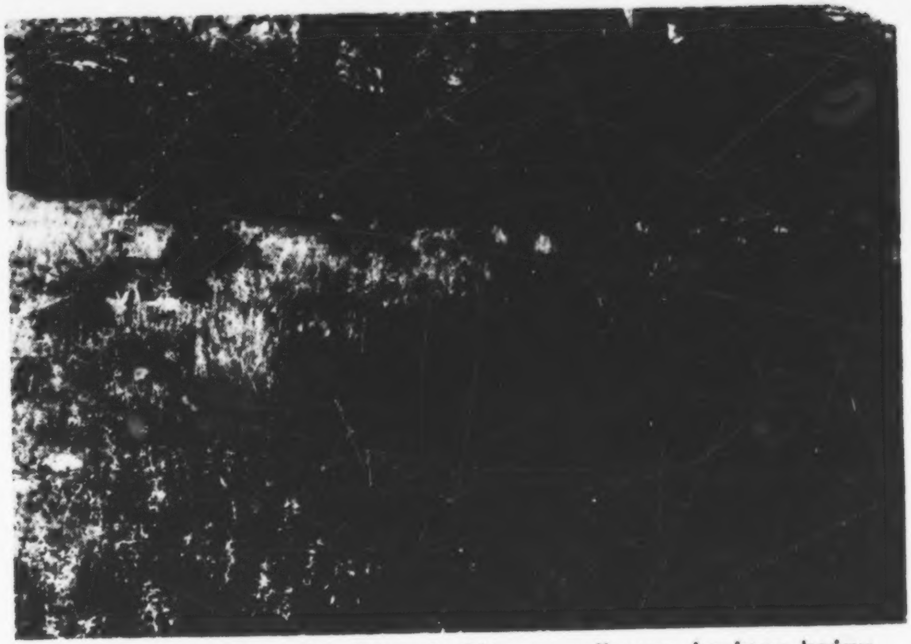

Figure 91. Grassland Bench Site; redberry juniper-hairy grama-blue grama community.

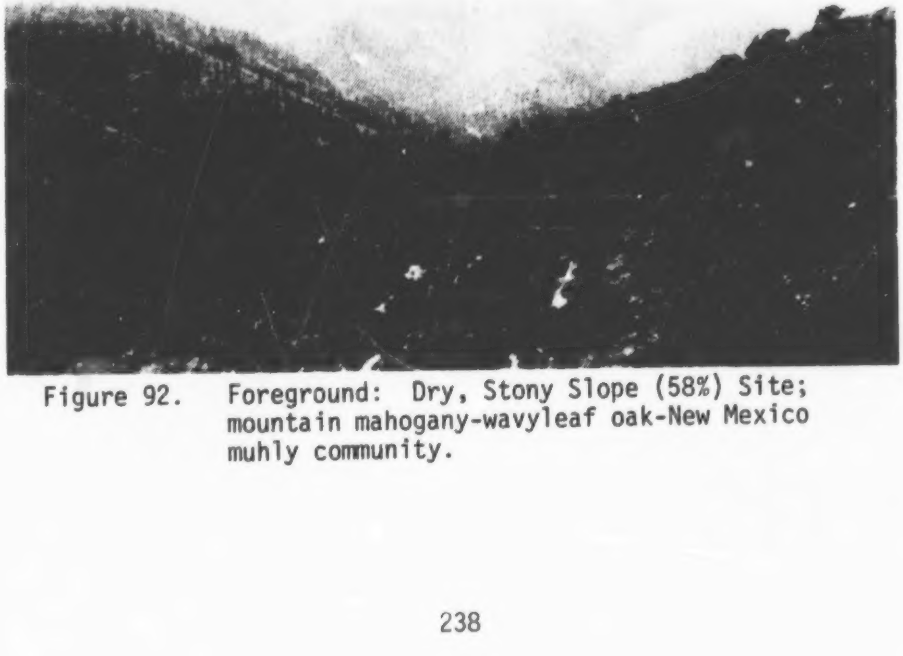

Figure 92. Foreground: Dry, Stony Slope (58%) Site; mountain mahogany-wavyleaf oak-New Mexico muhly community.

## TABLE 97. SITES AND COMMUNITIES OF WATERSHED 6

| Site | Community | Map Symbol |
|---|---|---|
| Steep Wooded Slope (49%) | Douglas fir-gambel oak-New Mexico muhly-littleawn needlegrass | 13C |
| | Douglas fir-gambel oak-southwestern white pine | 13D |
| Steep Intermediately Wooded (50%) | Alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly | 14A |
| Wooded Ridgetop | Pinyon pine-wavyleaf oak-New Mexico muhly | 12E |
| Dry, Stony Slope (58%) | Mountain mahogany-wavyleaf oak-New Mexico muhly | 4A |
| | Pinyon pine-mountain mahogany-desert ceanothus-New Mexico muhly | 4B |
| Bowl | Ponderosa pine-Arizona fescue-pringle needlegrass | 37A |
| Rocky, Lower Slope (5800 ft.) | Wavyleaf oak-smooth sotol-bull muhly-pine muhly | 38A |
| | Smooth sotol-wavyleaf oak-sideoats grama-bull muhly | 38B |
| Steep Open | Wavyleaf oak-smooth sotol-sideoats grama | 30B |
| (Inclusion) | Big-tooth maple-wavyleaf oak-green sprangletop | 39A |
| Creek Bottom | Redberry juniper-smooth sotol-hairy grama | 40A |
| | Chinkapin oak-big-tooth maple-wavyleaf oak | 40B |
| | Not sampled | 41A |

## TABLE 98. VEGETATIVE COMPOSITION WATERSHED 6

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| 4A | 20.2 | 2784 | 4.35 |
| 4B | 6.2 | 854 | 1.33 |
| 12E | 2.4 | 331 | .52 |
| 13C | 13.5 | 1,862 | 2.91 |
| 13A | 0.1 | 14 | .02 |
| 13D | 11.2 | 1,543 | 2.41 |
| 14A | 6.0 | 827 | 1.29 |
| 14B | 1.0 | 138 | .22 |
| 16A | 1.4 | 193 | .30 |
| 30B | 7.1 | 979 | 1.53 |
| 32A | 1.6 | 220 | .34 |
| 35B | 0.5 | 69 | .11 |
| 37A | 7.0 | 965 | 1.51 |
| 38A | 2.6 | 359 | .56 |
| 38B | 0.5 | 69 | .11 |
| 39A | 0.2 | 28 | .04 |
| 40A | 2.0 | 276 | .43 |
| 40B | 1.1 | 152 | .24 |
| 41A | 15.4 | 2,123 | 3.31 |
|  | 100.0 | 13,786 | 21.53* |

* Includes only area within National Park boundary

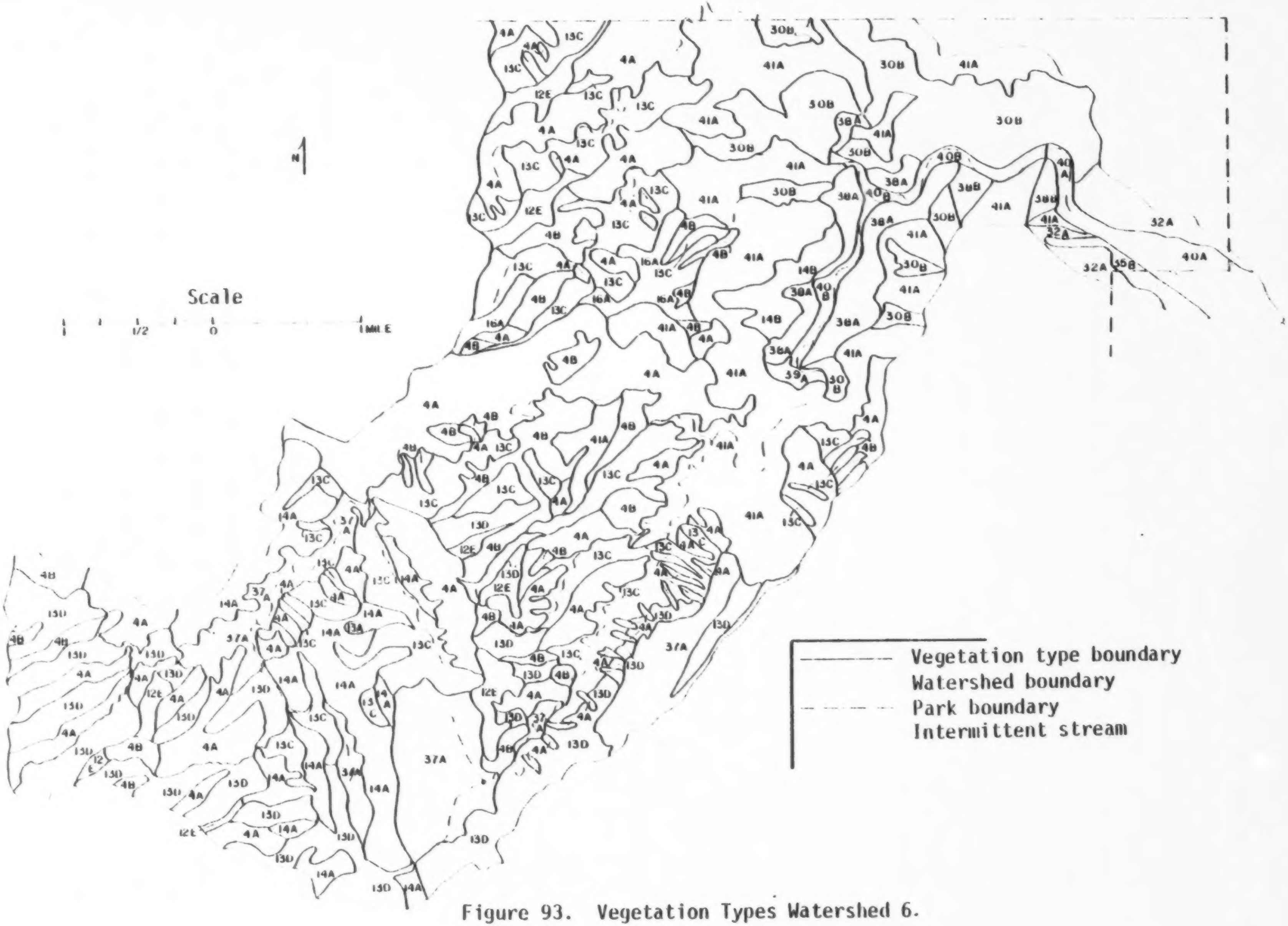

Figure 93. Vegetation Types Watershed 6.

## STEEP WOODED SLOPE (49%)--SITE

The Steep Wooded Slope (49%) site, described in Watershed 1 (Table 52) occurred in Watershed 6 on northeastern to northwestern aspects at elevations ranging from 7100 to 8200 ft. At the lower elevations of the site in Watershed 6 (7100-7800 ft.), the Douglas fir-Gambel oak-New Mexico muhly-littleawn needlegrass community (Table 99) was found. Although New Mexico muhly was the most common grass in this community, its abundance and frequency were less than in the Douglas fir-New Mexico muhly community of the same site in Watershed 1. Also, littleawn needlegrass increased in importance in the Douglas fir-Gambel oak-New Mexico muhly-littleawn needlegrass community, joining New Mexico muhly as an understory codominant. Total overstory increased to 59%. Both ponderosa pine and southwestern white pine contributed significantly to the overstory at the 6-20 and greater than 20 ft. levels. Gambel oak was also very important in this community. Other species included bigtooth maple, cliff fendlerbush, wavyleaf oak and Utah serviceberry. Alligator juniper was uncommon. Creeping barberry was the most common forb. Allium spp. and deer ears (Swertia radiata) were present in smaller amounts.

The Douglas fir-Gambel oak-southwestern white pine community (Bunting, 1978, Table 51) occurred on northeastern to northwestern aspects at elevations generally greater than 7600-7800 ft. This community occurred on slightly steeper slopes than a related community, the Douglas fir-southwestern white pine-grass community (Bunting, 1978, Table 50). Both communities were found on similar aspects at similar elevations, and for mapping purposes, we have designated the Douglas fir-Gambel oak-southwestern white pine community. This community is closely related to the Douglas fir-Gambel oak-New Mexico muhly-littleawn needlegrass community, generally found at lower elevations, regarding overstory species. However, New Mexico muhly was absent from the Douglas fir-Gambel oak-southwestern white pine community, while it was a codominant grass in the Douglas fir-Gambel oak-New Mexico muhly-littleawn needlegrass community. New Mexico muhly was also very abundant in the Douglas fir-New Mexico muhly community of Watershed 1.

It appears that on mostly non-calcareous soils, the upper elevational range of New Mexico muhly is about 7600-7900 ft. That is, we recorded

TABLE 99. SITE CHARACTERISTICS OF THE STEEP WOODED SLOPE (48%) SITE IN WATERSHED 6 AND SPECIES COMPOSITION OF THE DOUGLAS FIR-GAMBEL OAK-NEW MEXICO MUHLY-LITTLEAWN NEEDLEGRASS COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 7400 | 7100-7800 | | | | | | | | |
| Slope (%) | 45 | 35-50 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 1 | 0-2 | | | | | | | | |
| Litter | 74 | 68-78 | | | | | | | | |
| Small rock | 12 | 8-18 | | | | | | | | |
| Large rock | 10 | 6-16 | | | | | | | | |
| Bare ground | 3 | 0-6 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 28 | 14-38 | | | | | | | | |
| 6-20' | 19 | 0-32 | | | | | | | | |
| > 20' | 12 | 0-22 | | | | | | | | |
| Total | 59 | 48-70 | | | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 15 | 0-44 | | | | | | |
| *Stipa lobata*--littleawn needlegrass | | | 14 | 0-22 | | | | | | |
| *Carex* spp.--sedge | | | 6 | 6 | | | | | | |
| *Pseudotsuga menziesii*-Douglas fir | | | 3 | 0-4 | 7 | 0-12 | 11 | 6-20 | 8 | 4-14 |
| *Quercus gambelii*--Gambel oak | | | 11 | 10-14 | 2 | 0-24 | 3 | 0-4 | | |
| *Pinus ponderosa*--ponderosa pine | | | | | 1 | 0-2 | 4 | 0-12 | 5 | 0-8 |
| *Pinus strobiformis*--southwestern white pine | | | | | 1 | 0-2 | 5 | 0-10 | 3 | 0-8 |

Data based on transects 2193-2195

Aspects: Northwestern to northeastern

the species at and below these elevations, as did Bunting (1978). New Mexico muhly occurs at much higher elevations on soils which have a stronger calcareous influence. There are some indications (Shreve, 1922; Billings, 1952) that soils derived from limestone and other rocks rich in calcium enable certain plants to extend their elevational range. On the higher elevation northern aspects, cooler temperatures result in a more effective soil moisture regime which leaches calcium from the soil; under these conditions, these elevations are too high for New Mexico muhly. On southern aspects at the higher elevations, however, warmer temperatures reduce the amount of soil moisture, and soils remain calcareous (in part); these soils can support New Mexico muhly at higher than usual elevations. We have chosen an elevation of 7600-7900 ft. as the dividing elevational line between the Douglas fir-Gambel oak-southwestern white pine community and the Douglas fir-Gambel oak-New Mexico muhly-littleawn needlegrass community in Watershed 6, where the former community was generally found at and above these elevations and the latter community was generally found at and below these elevations. It should be noted that aerial photographic signatures are often similar for the two communities.

The understory of the Douglas fir-Gambel oak-southwestern white pine community is light and made up mostly of shrubs, for example, Utah serviceberry, white honeysuckle (Lonicera albiflora) and longtube snowberry (Symphoricarpos longiflorus). Mountain brome (Bromus anomalus), littleawn needlegrass and Carex spp. were the most important grasses (Bunting, 1978, Table 51).

## STEEP INTERMEDIATELY WOODED SLOPE (50%)--SITE

At elevations ranging from 7200-8000 ft. on southeastern to northeastern aspects, the Steep Intermediately Wooded Slope (50%) site, described in Watershed 1 (Table 55) occurred. The typical expression of the site in Watershed 6, as in Watershed 1, was the alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community. However, Bunting (1978) found less pine muhly in the same area. In Watershed 6, this site and community was mapped in some topographic positions which were not as steep as the average slope of the site in Watershed 1.

## WOODED RIDGETOP--SITE

Bunting (1978, Table 44) described a pinyon pine-wavyleaf oak-New Mexico muhly community in McKittrick Canyon on all aspects except steep northern slopes above 6900 ft. This community is closely related to the pinyon pine-New Mexico muhly community of the Wooded Ridgetop site of Watershed 1 (Table 50) and probably represents a phase of it. New Mexico muhly and Carex spp. were the most important understory species in both communities, with significant amounts of sideoats grama and littleawn needlegrass. Dominant overstory species were also similar in both communities. Although the shrub and grass components of the pinyon pine-wavyleaf oak-New Mexico muhly community were somewhat similar to the alligator juniper-wavyleaf oak-New Mexico muhly-pine muhly community found at lower elevations in the Steep Intermediately Wooded Slope site, the two communities differed. The pinyon pine-wavyleaf oak-New Mexico muhly community had less pine muhly, and pinyon pine replaced alligator juniper as the dominant overstory species. Also, they generally occupied different topographic positions.

## DRY, STONY SLOPE (58%)--SITE

A considerable portion of McKittrick Canyon is made up of extensive southeastern to southwestern aspects at 6600-8200 ft. Many portions of these slopes are free of tree canopy cover, and the mountain mahogany-wavyleaf oak-New Mexico muhly community of the Dry, Stony Slope (58%) site of Watershed 1 (Table 36, Figure 92) was mapped in these areas.

Some areas of these aspects are sparsely wooded with pinyon pine. Bunting (1978) described a pinyon pine-mountain mahogany-desert ceanothus-New Mexico muhly community in these areas, where this type represents a transition between the mountain mahogany-wavyleaf oak-New Mexico muhly community (Table 36) and the pinyon pine-New Mexico muhly community (Table 50). Therefore, we have mapped a pinyon pine-mountain mahogany-desert ceanothus-New Mexico muhly community on these partially wooded aspects, and interpret this vegetation to be a mixture of the mountain mahogany-wavyleaf oak-New Mexico muhly and pinyon pine-New Mexico muhly communities.

## BOWL--SITE

The Ponderosa pine-Arizona fescue-pringle needlegrass community occurred throughout broad mountain canyon bottoms and much of the Bowl area (Bunting, 1978, Table 54). These regions are designated the Bowl site (Figure 94). Elevations throughout the site ranged from 7200 to 8000 ft. The site occurred on all aspects, and slopes were gentle to level. Ponderosa pine was the dominant overstory species, although its frequency in plots was low. There were also small amounts of alligator juniper and Gambel oak. Arizona fescue (_Festuca arizonica_) and pringle needlegrass were codominant grasses, with smaller amounts of blue grama, curlyleaf muhly and junegrass (_Koelaria pyramidata_). White sage was the most important forb.

## ROCKY, LOWER SLOPE (5800 ft.)--SITE

The Rocky, Lower Slope (5800 ft.) site (Table 100) occurred on the lower slope positions at 5400-6000 ft. where slope colluvium made up, in part, the parent material. There was only 6% vegetative cover, with 38% litter, 25% small rock and 30% large rock.

The wavyleaf oak-smooth sotol-bull muhly-pine muhly community (Table 101, Figure 95) occurred on the Rocky, Lower-Slope (5800 ft.) site. This corresponds well with Bunting's (1978, Tables 38, 41) data. Wavyleaf oak and smooth sotol dominated the shrub layer of the community, contributing 10% and 9%, with 12% and 4%, of the species composition and overstory, respectively. Other species included mountain mahogany, _Quercus_ spp., New Mexico agave, skeleton goldeneye, cliff fendlerbush and smallseed sacahuista. Overstory totaled 24%, and shrubs made up 36% of the vegetation. There were also scattered junipers, Texas madrones, oaks and pinyon pine. A wide variety of grasses occurred, comprising 51% of the vegetation. Bull muhly (14%) and pine muhly (10%) were the dominant species, with smaller amounts of blue threeawn (5%), sideoats grama (4%) and wolftail, curlyleaf muhly, hairy grama, slim tridens and plains lovegrass, each making up 2%. Common forbs included plains fleabane (3%), needleleaf bluets (2%) and _Galium_ spp. (2%).

Figure 94. Bowl Site; ponderosa pine-Arizona fescue-pringle needlegrass community.

Figure 95. Rocky, Lower Slope (5800 ft.) Site; wavyleaf oak-smooth sotol-bull muhly-pine muhly community.

TABLE 100. SITE CHARACTERISTICS OF THE ROCKY, LOWER-SLOPE (5800 FT.)--SITE

| Site Characteristics | Average | Range |
|---|---|---|
| Elevation (ft.) | 5500 | 5100-6300 |
| Slope (%) | 51 | 35-70 |
| Ground cover (%) | | |
| Vegetation | 7 | 4-8 |
| Litter | 36 | 28-42 |
| Small rock | 16 | 8-28 |
| Large rock | 40 | 30-56 |
| Bare ground | 1 | 0-2 |
| Cryptogam | 0 | -- |
| Overstory (%) | | |
| 0-6' | 22 | 12-36 |
| 6-20' | 0 | -- |
| > 20' | 0 | -- |
| Total | 22 | 12-36 |
| Grasses (%) | 44 | 30-52 |
| Forbs (%) | 17 | 8-26 |
| Shrubs (%) | 39 | 33-44 |

Data based on transects 1-4, 13, 14 (1979)

Aspects: All

TABLE 101. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMOOTH SOTOL-BULL MUHLY-PINE MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % 0-6' | | Overstory % 6-20' | | Overstory % > 20' | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5800 | 5400-6000 | | | | | | | | |
| Slope (%) | 65 | 59-70 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 6 | 4-8 | | | | | | | | |
| Litter | 38 | 34-42 | | | | | | | | |
| Small rock | 25 | 22-28 | | | | | | | | |
| Large rock | 30 | -- | | | | | | | | |
| Bare ground | 1 | 0-2 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 24 | 12-36 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 24 | 12-36 | | | | | | | | |
| *Muhlenbergia emersleyi*--bull muhly | | | 14 | 4-24 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 10 | 2-18 | | | | | | |
| *Aristida glauca*--blue threeawn | | | 5 | 4-6 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 5 | 2-6 | | | | | | |
| *Quercus undulata*--wavyleaf oak | | | 10 | 6-14 | 9 | 2-16 | | | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 12 | 12 | 4 | 4 | | | | |
| *Quercus* spp.--oak | | | 2 | 0-4 | 2 | 2 | | | | |
| *Cercocarpus montanus* var. *paucidentatus*--mountain mahogany | | | 2 | 2 | 1 | 0-2 | | | | |

Data based on transects 13, 14 (1979)

Aspects: All

A closely related community, the smooth sotol-wavyleaf oak-sideoats grama-bull muhly community (Table 102, Figure 96) occurred on northeastern aspects with less small rock, more large rock and more moderate slopes. Shrub and grass composition of this community, the wavyleaf oak-smooth sotol-bull muhly-pine muhly community and the wavyleaf oak-smooth sotol-sideoats grama community (discussed below) were similar, although the relative proportions of the dominants differed among the three communities.

## STEEP OPEN--SITE

Southern to southwestern aspects from 5400-6400 ft. throughout much of the northern McKittrick Canyon had site characteristics similar to the Steep Open site of Watershed 7 (Table 85). Also, aerial photographic signatures were similar. For mapping purposes, these areas in McKittrick Canyon will be mapped into the Steep Open site. However, they generally occur on more moderate slopes (51%), have more vegetative ground cover (10%), litter (32%), overstory (24%) and less small rock (27%). This site is extensive in northern McKittrick Canyon and intergrades elevationally with the Dry, Rocky Slope (58%) site, characterized in Watershed 1 at 6700-7600 ft., and also found in southern McKittrick Canyon up to 8200 ft.

The typical vegetation of the site in McKittrick Canyon was the wavyleaf oak-smooth sotol-sideoats grama community (Table 103, Figure 97). Wavyleaf oak and smooth sotol dominated both the species composition (13% and 9%, respectively) and overstory (11% and 9%, respectively). However, a wide variety of shrubs were present, comprising 46% of the vegetation. Lecheguilla (9%) was common, with smaller amounts of mountain mahogany, evergreen sumac and herba de pasmo. Tree overstory was absent. Many grasses occurred, the most common of which were sideoats grama (9%), plains lovegrass (7%) and littleawn needlegrass (6%). Blue threeawn, little bluestem, pine muhly, New Mexico muhly and bull muhly were present in amounts ranging from 1-3%.

Although site characteristics of the Steep Open site in McKittrick Canyon, and the Rocky, Lower-Slope (5800 ft.) site were similar, the sites were distinct, as were the communities they supported. Soils of

## TABLE 102. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE SMOOTH SOTOL-WAVYLEAF OAK-SIDEOATS GRAMA-BULL MUHLY COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5360 | 5100-6300 | | | | | | | | |
| Slope (%) | 44 | 35-55 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 7 | 4-8 | | | | | | | | |
| Litter | 35 | 28-42 | | | | | | | | |
| Small rock | 12 | 8-18 | | | | | | | | |
| Large rock | 45 | 36-56 | | | | | | | | |
| Bare ground | 1 | 0-2 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 21 | 12-26 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 21 | 12-26 | | | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 12 | 8-18 | | | | | | |
| Muhlenbergia emersleyi--bull muhly | | | 10 | 6-14 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 6 | 0-8 | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 5 | 2-10 | | | | | | |
| Dasylirion leiophyllum--smooth sotol | | | 10 | 6-13 | | | | | | |
| Quercus undulata--wavyleaf oak | | | 7 | 6-8 | 8 | 4-10 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 4 | 0-6 | 2 | 0-4 | | | | |
| Rhus virens--evergreen sumac | | | 5 | 2-10 | 1 | 0-2 | | | | |
| Nolina micrantha--smallseed sacahuista | | | 4 | 2-8 | 4 | 0-8 | | | | |
| Agave lecheguilla-lecheguilla | | | 3 | 0-4 | | | | | | |

Data based on transects 1-4 (1979)

Aspects: Northeastern

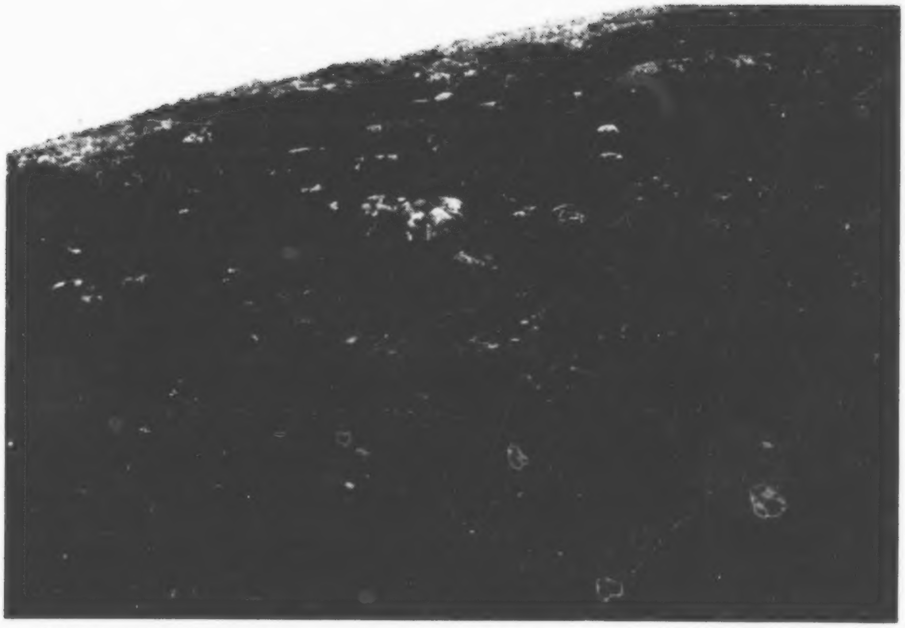

Figure 96. Rocky, Lower-Slope (5800 ft.) Site; smooth sotol-wavyleaf oak-sideoats grama-bull muhly community.

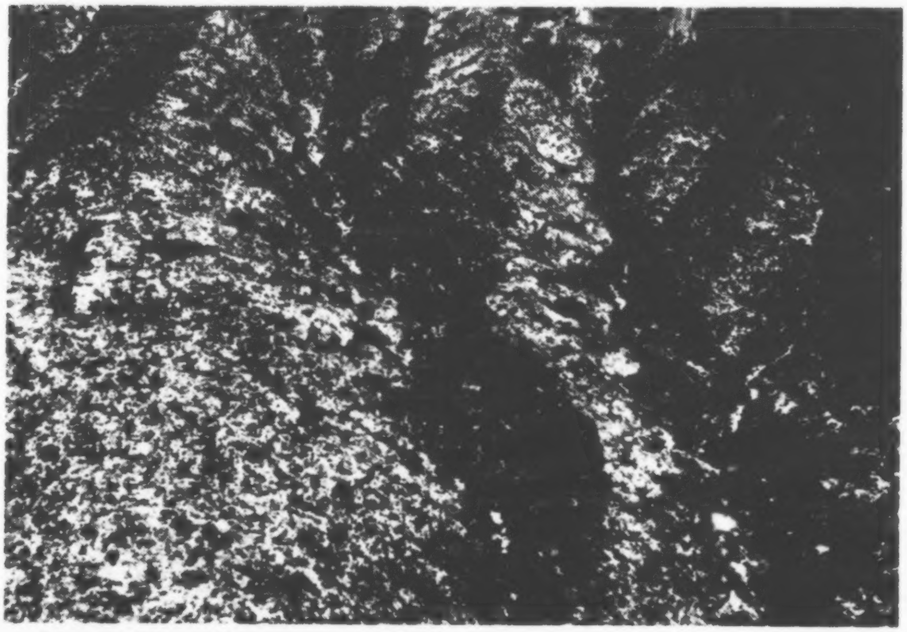

Figure 97. Steep Open Site; wavyleaf oak-smooth sotol-sideoats grama community.

TABLE 103. SITE CHARACTERISTICS OF THE STEEP OPEN SITE AND SPECIES COMPOSITION OF THE WAVYLEAF OAK-SMOOTH SOTOL-SIDEOATS GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5940 | 5100-7000 | | | | | | | | |
| Slope (%) | 51 | 47-53 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 10 | 8-14 | | | | | | | | |
| Litter | 32 | 28-40 | | | | | | | | |
| Small rock | 27 | 22-36 | | | | | | | | |
| Large rock | 30 | 24-34 | | | | | | | | |
| Bare ground | 1 | 0-4 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 24 | 18-32 | | | | | | | | |
| 6-20' | 0 | -- | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 24 | 18-32 | | | | | | | | |
| Grasses (%) | 41 | 30-52 | | | | | | | | |
| Forbs (%) | 13 | 8-16 | | | | | | | | |
| Shrubs (%) | 46 | 36-56 | | | | | | | | |
| Bouteloua curtipendula--sideoats grama | | | 9 | 0-14 | | | | | | |
| Eragrostis lugens--plains lovegrass | | | 7 | 0-12 | | | | | | |
| Schizachyrium scoparium--littleawn bluestem | | | 3 | 0-10 | | | | | | |
| Aristida glauca--blue threeawn | | | 3 | 0-4 | | | | | | |
| Muhlenbergia dubia--pine muhly | | | 3 | 0-8 | | | | | | |
| Quercus undulata--wavyleaf oak | | | 13 | 2-28 | 11 | 2-18 | | | | |
| Dasylirion leiophyllum--smooth sotol | | | 9 | 0-16 | 9 | 4-14 | | | | |
| Cercocarpus montanus var. paucidentatus--mountain mahogany | | | 4 | 2-8 | 1 | 0-4 | | | | |
| Agave lecheguilla--lecheguilla | | | 9 | 2-18 | < 1 | 0-2 | | | | |
| Rhus virens--evergreen sumac | | | 3 | 0-6 | < 1 | 0-2 | | | | |

Data based on transects 5-9 (1979)

Aspects: South, southwestern

the Rocky, Lower-Slope (5800 ft.) site supporting the wavyleaf oak-smooth sotol-bull muhly-pine muhly community were derived, in part, from slope colluvium, while soils of the Steep Open site in McKittrick Canyon supporting the wavyleaf oak-smooth sotol-sideoats grama community were derived from eroding limestone bedrock (Bunting, 1978). In addition, the two sites are found in very different topographic positions. Regarding the identity of the two communities, although the data indicate that shrub composition was similar, field observations show that there is tree overstory in the wavyleaf oak-smooth sotol-bull muhly-pine muhly community, but not in the wavyleaf oak-smooth sotol-sideoats grama community. Also, the grass component of the vegetation was different between the two communities.

Very steep (69%) northern to northeastern aspects in lower McKittrick Canyon were difficult to characterize. A big-tooth maple-wavyleaf oak-green sprangletop community (Table 104) was identified below Turtle Rock, but because of limited sampling, is assigned only an inclusion status. Bunting (1978, Table 53) identified a big-tooth maple-Douglas fir-Knowlton hop-hornbeam community on similar topographic positions throughout McKittrick Canyon. However, this community and the southwestern white pine-Gambel oak-Knowlton hop-hornbeam community (Bunting, 1978, Table 52) occupy the steeper portions of northern to northwestern aspects which we have generalized to the Douglas fir-Gambel oak-southwestern white pine community (see above). Therefore, although we have mapped the big-tooth maple-wavyleaf oak-green sprangletop in only one location as an inclusion, it is doubtless a repeating community throughout the watershed where the topography can support it (very steep northern slopes).

Shrubs and trees composed 22% of the vegetation of the big-tooth maple-wavyleaf oak-green sprangletop community. Big-tooth maple dominated the overstory, accounting for 21%. Also present were ponderosa pine and Douglas fir, although the latter species did not occur in the samples. Velvet ash (*Fraxinus velutina*), chinkapin oak and Texas madrone were other tree species in the community. Many shrubs occurred, the most common of which was wavyleaf oak, contributing 5% to the species composition and 9% to the overstory. Other species included *Quercus*

TABLE 104. SITE CHARACTERISTICS AND SPECIES COMPOSITION OF THE BIG-TOOTH MAPLE-WAVYLEAF OAK-GREEN SPRANGLETOP COMMUNITY INCLUSION

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5780 | 5400-5800 | | | | | | | | |
| Slope (%) | 69 | 68-71 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 7 | 6-8 | | | | | | | | |
| Litter | 53 | 48-58 | | | | | | | | |
| Small rock | 8 | 6-10 | | | | | | | | |
| Large rock | 30 | 24-34 | | | | | | | | |
| Bare ground | 2 | 0-6 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 30 | 12-46 | | | | | | | | |
| 6-20' | 8 | 2-12 | | | | | | | | |
| > 20' | 5 | 0-16 | | | | | | | | |
| Total | 43 | 14-74 | | | | | | | | |
| Grasses (%) | 36 | 24-46 | | | | | | | | |
| Forbs (%) | 40 | 28-48 | | | | | | | | |
| Shrubs (%) | 22 | 14-26 | | | | | | | | |
| *Leptochloa dubia*--green sprangletop | | | 9 | 2-16 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 8 | 0-18 | | | | | | |
| *Muhlenbergia rigens*--deergrass | | | 5 | 0-10 | | | | | | |
| *Muhlenbergia dubia*--pine muhly | | | 5 | 2-8 | | | | | | |
| *Muhlenbergia pauciflora*--New Mexico muhly | | | 5 | 2-6 | | | | | | |
| *Acer grandidentatum*--big-tooth maple | | | 3 | 0-6 | 14 | 6-28 | 7 | 0-14 | | |
| *Quercus undulata*--wavyleaf oak | | | 5 | 2-8 | 9 | 2-18 | | | | |
| *Fraxinus velutina*--velvet ash | | | | | 1 | 0-2 | 1 | 0-4 | | |
| *Pinus ponderosa*--ponderosa pine | | | < 1 | 0-2 | | | 1 | 0-4 | | |
| *Arbutus xalapensis*--Texas madrone | | | < 1 | 0-2 | 1 | 0-4 | < 1 | 0-2 | | |

Data based on transects 10-12 (1979)

Aspects: Northern-northeastern

spp., plume brickellbush, mountain mahogany, smooth sotol, tatalencho, Hitchcock mockorange (Philadelphus hitchcockianus), gray oak, skunkbush and cliff fendlerbush. Grasses comprised 37% of the vegetation. Green sprangletop (9%) and sideoats grama (8%) were the most common species, with smaller amounts of deergrass (Muhlenbergia rigens) (5%), pine muhly (5%) and New Mexico muhly (5%). Forbs made up 40% of the vegetation, but few species were present. Plains fleabane (23%), Notholaena spp. (11%), and white sage (10%) were the most common species.

## CREEK BOTTOM--SITE

The Creek Bottom site occurred along McKittrick Stream. At elevations up to about 5050 ft., site characteristics showed the same general trends as the Shrub Slope Bench site (Table 92) of Watershed 7: litter (38%) and small rock (35%) dominated the ground cover, with 10% bare ground. However, there was much more vegetative ground cover (13%). The redberry juniper-smooth sotol-hairy grama community (Table 105, Figure 98) was found on this site. Redberry juniper dominated the overstory, with 8% at the 6-20 ft. level. Smooth sotol was also common, along with smaller amounts of catclaw mimosa, evergreen sumac and soaptree yucca. Shrubs made up 12% of the vegetation and accounted for 14% overstory. Hairy grama (25%) was the dominant understory species. Also present were wolftail (10%), cane bluestem (8%) and smaller amounts of slim tridens, green sprangletop, sideoats grama and Aristida spp. Euphorbia spp. was locally common, along with smaller amounts of Chamaesaracha spp., noseburn, hairy evolvulus, knotweed leafflower and multi-flower puccoon (Lithosperum multiflorum). This community was somewhat related to the Quercus-redberry juniper-plains lovegrass community of the Shrub Slope Bench site of Watershed 7.

In other areas of the site at these lower elevations, Bunting (1978, Table 57) identified a gray oak-sideoats grama-pine muhly community, which was similar to the Quercus-redberry juniper-plains lovegrass community of the Shrub Slope Bench site of Watershed 7.

At the higher elevations of the site (mostly greater than 5050 ft.), conditions were generally more mesic. In these areas, Bunting (1978, Table 58) described a chinkapin oak-big-tooth maple-wavyleaf oak community (Figure 99). Chinkapin oak, big-tooth maple and alligator juniper

TABLE 105. SITE CHARACTERISTICS OF THE CREEK BOTTOM SITE AND SPECIES COMPOSITION OF THE REDBERRY JUNIPER-SMOOTH SOTOL-HAIRY GRAMA COMMUNITY

| | Site Characteristics | | Species Composition % | | Overstory % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0-6' | | 6-20' | | > 20' | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Elevation (ft.) | 5100 | 4900-5100 | | | | | | | | |
| Slope (%) | 0 | 0 | | | | | | | | |
| Ground cover (%) | | | | | | | | | | |
| Vegetation | 13 | 8-16 | | | | | | | | |
| Litter | 38 | 22-58 | | | | | | | | |
| Small rock | 35 | 10-60 | | | | | | | | |
| Large rock | 4 | 0-8 | | | | | | | | |
| Bare ground | 10 | 2-14 | | | | | | | | |
| Cryptogam | 0 | -- | | | | | | | | |
| Overstory (%) | | | | | | | | | | |
| 0-6' | 15 | 4-22 | | | | | | | | |
| 6-20' | 1 | 0-2 | | | | | | | | |
| > 20' | 0 | -- | | | | | | | | |
| Total | 16 | 4-24 | | | | | | | | |
| Grasses (%) | 75 | 66-84 | | | | | | | | |
| Forbs (%) | 13 | 6-22 | | | | | | | | |
| Shrubs (%) | 12 | 8-16 | | | | | | | | |
| *Bouteloua hirsuta*--hairy grama | | | 25 | 18-38 | | | | | | |
| *Lycurus phleoides*--wolftail | | | 10 | 2-18 | | | | | | |
| *Bothriochloa barbinodis*--cane bluestem | | | 8 | 0-20 | | | | | | |
| *Tridens muticus*--slim tridens | | | 6 | 0-14 | | | | | | |
| *Leptochloa dubia*--green sprangletop | | | 5 | 0-14 | | | | | | |
| *Bouteloua curtipendula*--sideoats grama | | | 5 | 0-14 | | | | | | |
| *Aristida* spp.--threeawn | | | 5 | 2-10 | | | | | | |
| *Juniperus pinchoti*--redberry juniper | | | 1 | 0-4 | 8 | 0-14 | < 1 | 0-2 | | |
| *Dasylirion leiophyllum*--smooth sotol | | | 3 | 0-6 | 5 | 0-12 | | | | |
| *Mimosa biuncifera*--catclaw mimosa | | | 2 | 0-4 | < 1 | 0-2 | | | | |
| *Rhus virens*--evergreen sumac | | | 1 | 0-4 | | | | | | |
| *Yucca elata*--soaptree yucca | | | 1 | 0-4 | | | | | | |

Data based on transects 15-19 (1979)

Aspects: None

Figure 98. Creek Bottom Site; redberry juniper-smooth sotol-hairy grama community.

Figure 99. Creek Bottom Site; chinkapin oak-big-tooth maple-wavyleaf oak community.

were the dominant overstory species. Other species included ponderosa pine, Douglas fir and Texas madrone. Pinyon ricegrass, bull muhly and Carex spp. were the most important understory species. There were also drier areas at these slightly higher elevations, where vegetation related to the redberry juniper-smooth sotol-hairy grama community occurred.

# CHAPTER VII SOIL CONSIDERATIONS

## INTRODUCTION

Soil is recognized as a natural entity, the character of which is determined by the interaction of its parent material and environment over time. The nature of the soil on a particular watershed influences the hydrologic response of that watershed directly through such processes as infiltration and percolation while indirectly affecting the response through influencing the type of vegetation present.

In fulfilling the objectives of this research program, soils were surveyed and mapped on the five intensive study watersheds. During the course of the soil survey field work, it was noticed that soils on north- and south-facing slopes appeared to have perceptibly different profile morphologies and apparent differences in physical and chemical properties. Additional work was undertaken to intensively study the effects of elevation and aspect on soil morphological, physical (including temperature), and chemical properties at three locations in the park. Determinations of mean annual soil temperatures at 50 cm also permitted the proper placement of these soils into the United States comprehensive soil classification system.

Parameters governing the direction and rate of profile development include slope of the land surface, drainage, biotic activity (both plant and animal), and climatic variations. Research concerning effects of variations in the topographic factor in the United States has been limited to humid regions for the most part. Practically no information is available on the magnitude of differences in soil properties caused by aspect variations in the southwestern United States.

The results of the soil survey of the watersheds will be presented first followed by the additional work on the effects of elevation and aspect on soil profile development.

## SOIL SURVEY

Twenty-eight soil units were mapped on the five intensive watersheds. Figures 100 through 104 are maps presenting the distribution of soils on each watershed. Tables 106 through 111 present summaries of the percent composition and areal extent of soil types by watershed. Table 112 is the legend for the maps and Table 113 presents the classification of the various soil series described, according to the U.S. Soil Taxonomy.

TABLE 106. SOIL COMPOSITION WATERSHED 1

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| DRF | 12.9 | 408 | 0.64 |
| ORD | 0.4 | 13 | 0.02 |
| FDF | 23.8 | 751 | 1.17 |
| FDD | 24.1 | 762 | 1.19 |
| DRG | 5.4 | 170 | 0.27 |
| ERF | 15.0 | 474 | 0.74 |
| ERD | 13.3 | 422 | 0.66 |
| RRB | 4.1 | 129 | 0.20 |
| DRD | 1.0 | 31 | 0.05 |
|  | 100.0 | 3,160 | 4.94* |

* Includes only the area within the National Park boundary.

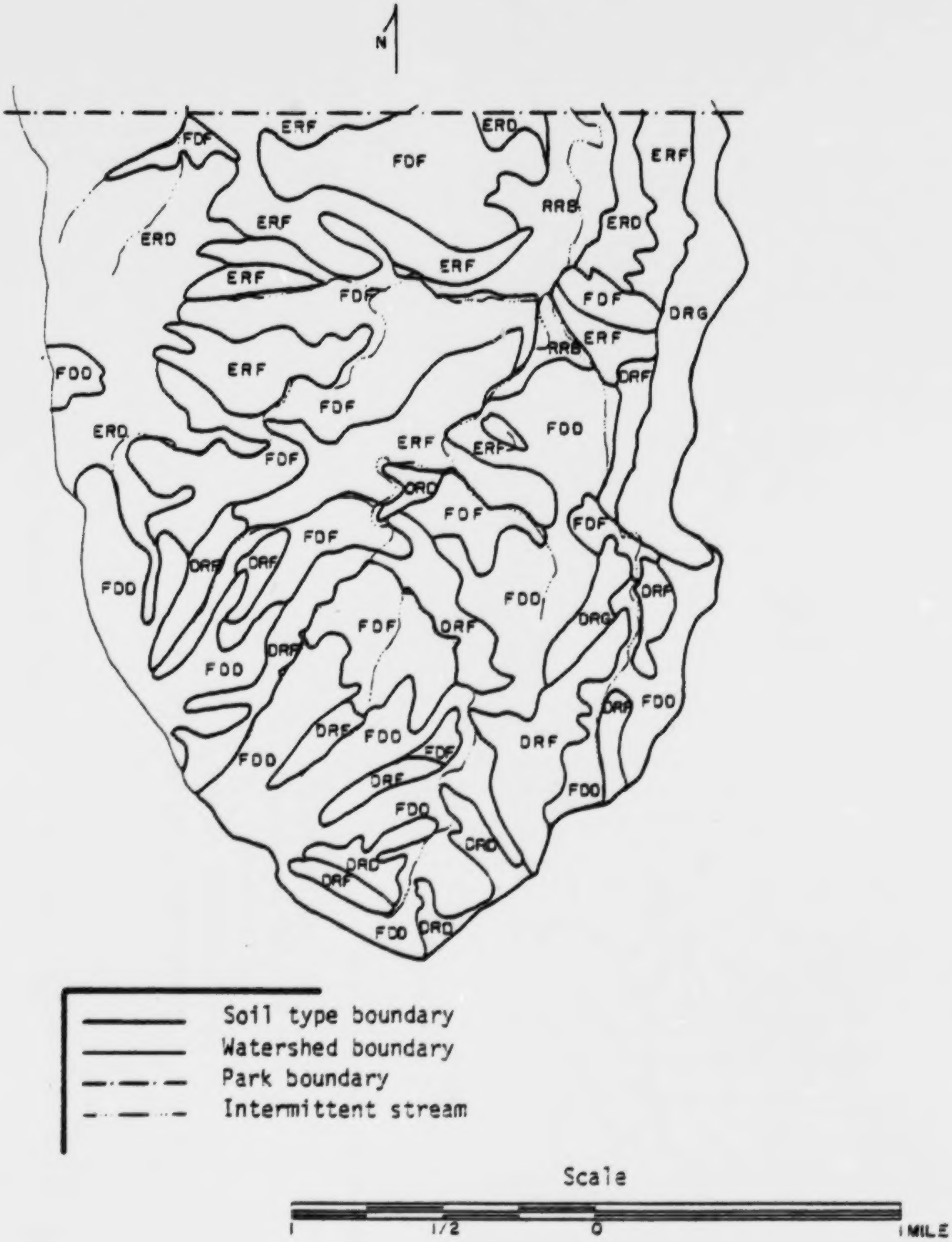

Figure 100. Soil Types Watershed 1.

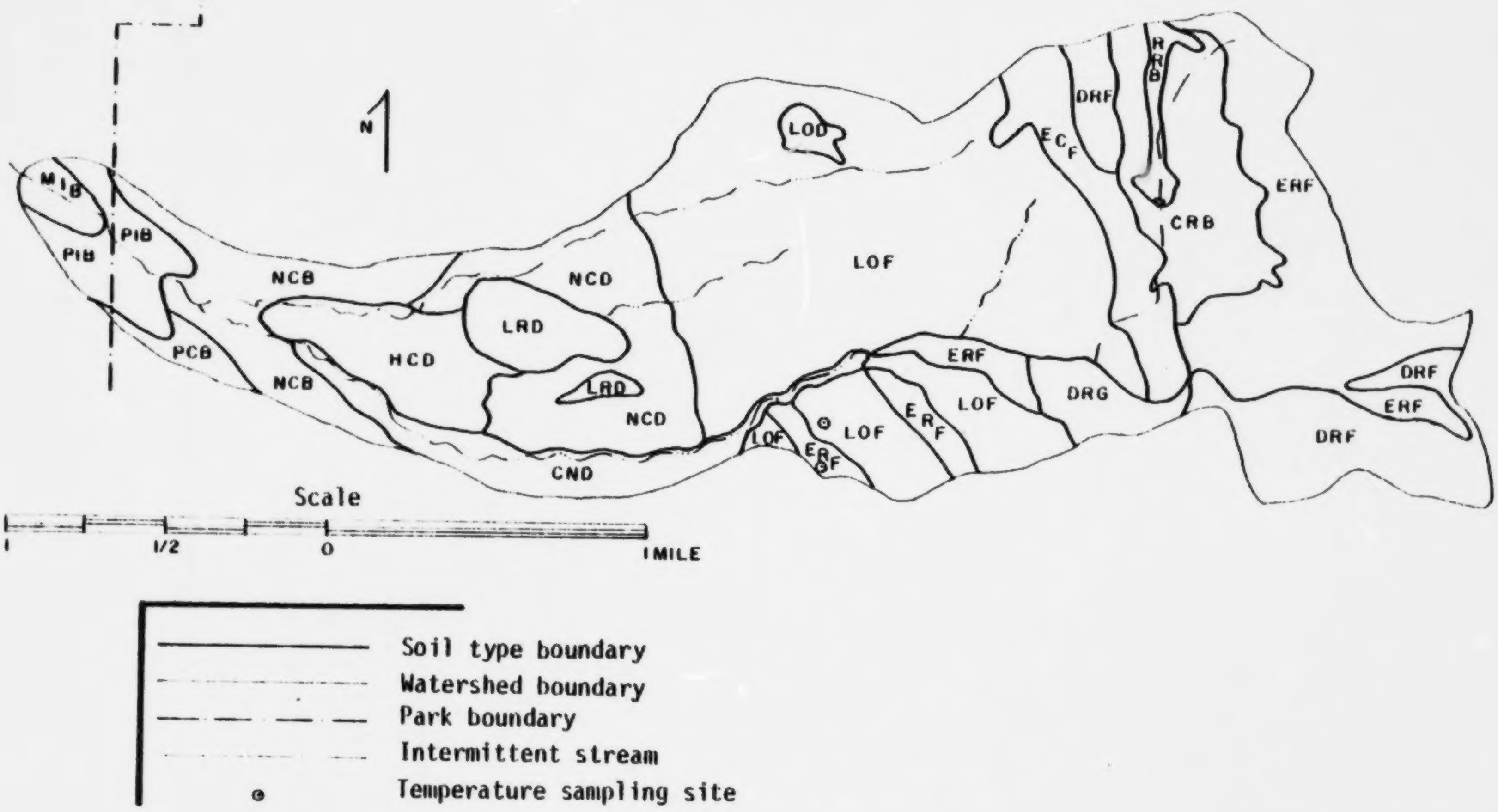

Figure 101. Soil Types Watershed 10A6.

## TABLE 107. SOIL COMPOSITION WATERSHED 10A6

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| DRF | 7.6 | 189 | 0.30 |
| DRG | 1.9 | 47 | 0.07 |
| ERF | 13.7 | 341 | 0.53 |
| LOF | 32.6 | 812 | 1.27 |
| CRB | 6.8 | 169 | 0.27 |
| RRB | 1.1 | 27 | 0.04 |
| LOD | 0.6 | 15 | 0.02 |
| LRD | 2.9 | 72 | 0.11 |
| NCD | 8.2 | 204 | 0.32 |
| HCD | 4.4 | 110 | 0.17 |
| CND | 4.7 | 117 | 0.18 |
| NCB | 5.8 | 145 | 0.23 |
| PCB | 1.1 | 27 | 0.04 |
| PIB | 3.2 | 80 | 0.13 |
| MIB | 1.0 | 25 | 0.04 |
| ECF | 4.4 | 110 | 0.17 |
|  | 100.0 | 2,490 | 3.89 |

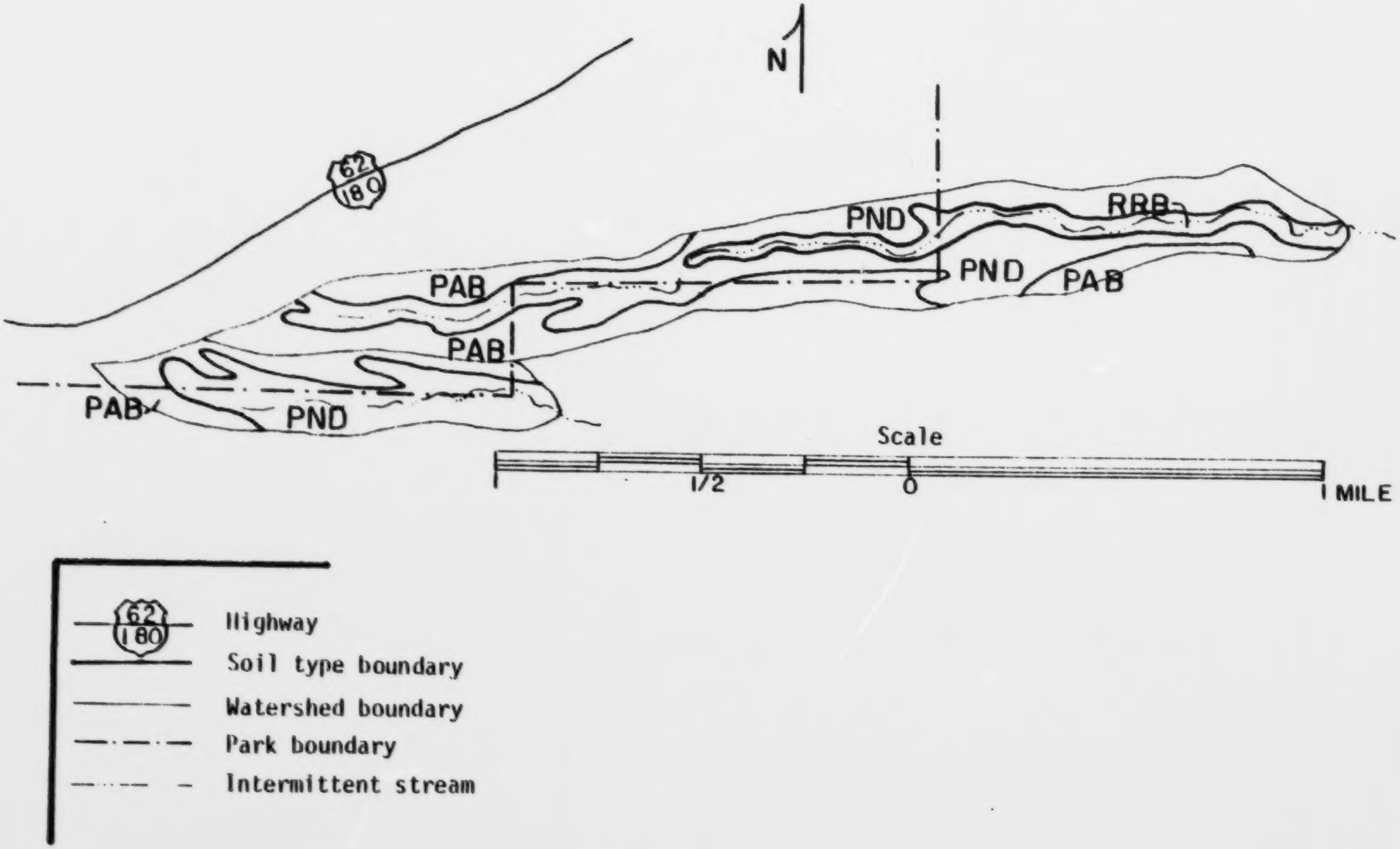

Figure 102. Soil Types Watershed 8B-8D.

TABLE 108. SOIL COMPOSITION WATERSHED 8B

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| PND | 62.8 | 58 | 0.09 |
| PAB | 37.2 | 38 | 0.06 |
| | 100.0 | 96 | 0.15 |

TABLE 109. SOIL COMPOSITION WATERSHED 8D

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| RRB | 15.6 | 51 | 0.08 |
| PAB | 34.9 | 122 | 0.19 |
| PND | 49.5 | 173 | 0.27 |
| | 100.0 | 346 | 0.54 |

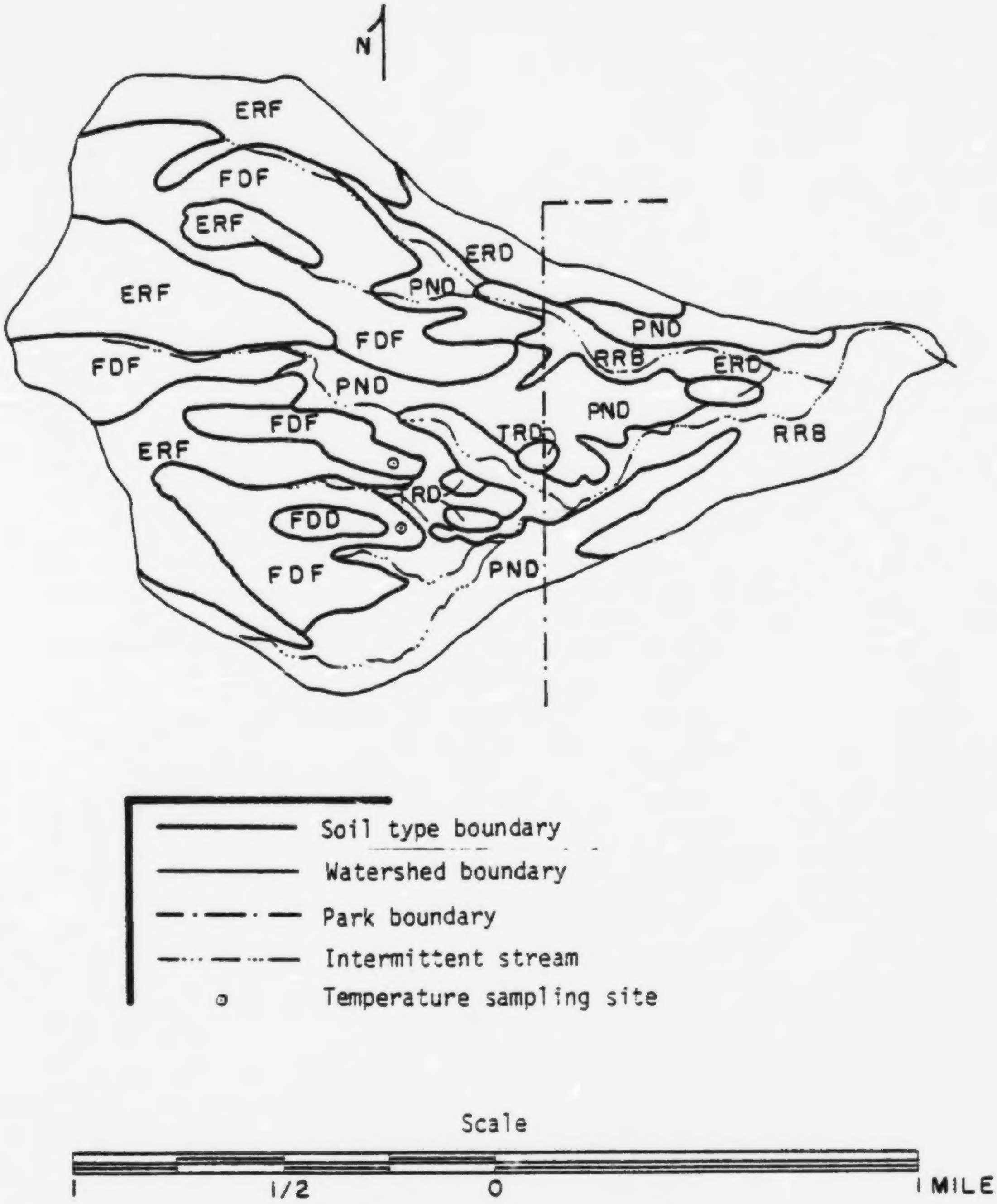

Figure 103. Soil Types Watershed 7.

## TABLE 110. SOIL COMPOSITION WATERSHED 7

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| ERF | 24.1 | 259 | 0.40 |
| FDF | 27.3 | 294 | 0.46 |
| FDD | 1.0 | 11 | 0.02 |
| PND | 25.4 | 274 | 0.42 |
| TRD | 1.0 | 10 | 0.02 |
| ERD | 4.1 | 44 | 0.07 |
| RRB | 17.1 | 184 | 0.29 |
|  | 100.0 | 1,076 | 1.68 |

## TABLE 111. SOIL COMPOSITION WATERSHED 6

| Map Symbol | Percent Area | Acres | Area Square Miles |
|---|---|---|---|
| FRD | 12.9 | 1,776 | 2.77 |
| FRF | 24.5 | 3,375 | 5.27 |
| FDF | 34.5 | 4,759 | 7.44 |
| FDD | 1.1 | 157 | 0.24 |
| RRB | 0.1 | 15 | 0.02 |
| ERF | 5.3 | 727 | 1.14 |
| RPG | 18.5 | 2,549 | 3.98 |
| ERD | 1.2 | 168 | 0.26 |
| PND | 0.3 | 38 | 0.06 |
| PPB | 1.6 | 223 | 0.35 |
|  | 100.0 | 13,786 | 21.53* |

* Includes only the area within the National Park boundary.

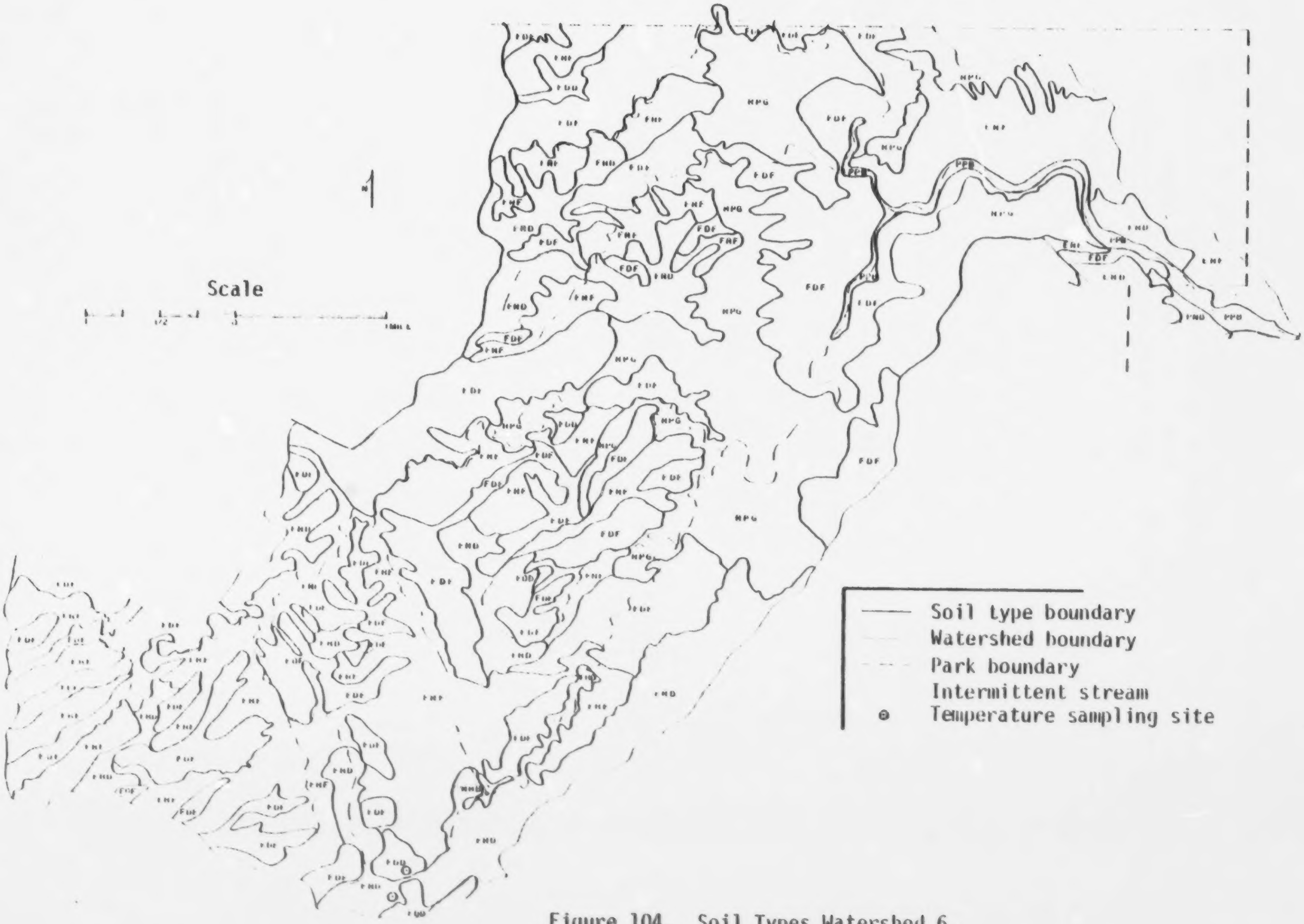

Figure 104. Soil Types Watershed 6.

## TABLE 112. SOIL MAP LEGEND

| Symbol | Unit | Percent Slope |
|---|---|---|
| CRB | Cuevoland Variant - Ruidoso - Deama Complex | 1-8 |
| CND | Canuito - Nickel Complex | 3-20 |
| DRD | Deama - Rock Outcrop - Flume Complex | 5-30 |
| DRF | Deama - Rock Outcrop - Flume Complex | 20-50 |
| DRG | Deama - Rock Outcrop - Complex | 40-50 |
| ECF | Ector - Rock Outcrop - Complex | 20-50 |
| ERD | Ector - Rock Outcrop - Flume Complex | 5-30 |
| ERF | Ector - Rock Outcrop - Flume Complex | 20-50 |
| FDD | Flume - Rock Outcrop - Deama Complex | 5-30 |
| FDF | Flume - Rock Outcrop - Deama Complex | 20-50 |
| FRD | Flume - Rock Outcrop Complex | 5-30 |
| FRF | Flume - Rock Outcrop Complex | 20-50 |
| HCD | Holloman - Canutio - Nickel Complex | 3-15 |
| LOD | Lozier - Rock Outcrop Complex | 5-30 |
| LOF | Lozier - Rock Outcrop Complex | 20-50 |
| LRD | Lozier - Rock Outcrop - Holloman Variant Complex | 5-30 |
| MIB | Mimbres - Torrifluvents Complex | 0-3 |
| NCB | Nickel - Canutio Complex | 1-5 |
| NCD | Nickel - Canutio Complex | 5-20 |
| ORD | Sombordoro - Rock Outcrop Complex | 5-30 |
| PAB | Penasco Soils | 0-3 |
| PCB | Pajarito - Canutio Complex | 1-5 |
| PIB | Pajarito - Bluepoint Complex | 1-5 |
| PND | Pena - Penasco Complex | 5-20 |
| PPB | Pena - Penasco-Haplustolls Association | 0-3 |
| RPG | Rock Outcrop - Deama Complex | 40-50 |
| RRB | Remunda - Ruidoso - Pena Complex | 0-5 |
| TRD | Travessilla - Rock Outcrop Complex | 5-30 |

## TABLE 113. CLASSIFICATION OF SOIL SERIES

| Series | Family | Subgroup | Order |
|---|---|---|---|
| Bluepoint | Mixed, thermic | Typic Torripsamments | Entisols |
| Canutio | Loamy-skeletal, mixed (calcareous), thermic | Typic Torriorthents | Entisols |
| Cuevoland | Fine-silty, mixed, mesic | Aridic Calciustolls | Mollisols |
| Deama | Loamy-skeletal, carbonatic, mesic | Lithic Calciustolls | Mollisols |
| Ector | Loamy-skeletal, carbonatic, thermic | Lithic Calciustolls | Mollisols |
| Flume* | Clayey-skeletal, carbonatic, mesic | Lithic Argiustolls | Mollisols |
| ----- | ----- | Fluventic Haplustolls | Mollisols |
| Holloman | Loamy, gypsic, thermic, shallow | Typic Torriorthents | Entisols |
| Lozier | Loamy-skeletal, carbonatic, thermic | Lithic Calciorthids | Aridisols |
| Mimbres | Fine-silty, mixed, thermic | Typic Camborthids | Aridisols |
| Nickel | Loamy-skeletal, mixed thermic | Typic Calciorthids | Aridisols |
| Pajarito | Coarse-loamy, mixed thermic | Typic Camborthids | Aridisols |
| Pena | Loamy-skeletal, mixed, mesic | Aridic Calciustolls | Mollisols |
| Penasco | Loamy-skeletal, carbonatic, mesic, shallow | Petrocalcic Calciustolls | Mollisols |
| Remunda | Fine, mixed, mesic | Aridic Argiustolls | Mollisols |
| Ruidoso | Fine, mixed, mesic | Pachic Argiustolls | Mollisols |
| Sombordoro | Clayey-skeletal, mixed mesic | Lithic Haplustalfs | Alfisols |
| ----- | ----- | Torrifluvents | Entisols |
| Travessilla | Loamy, mixed (calcareous), mesic | Lithic Ustic Torriorthents | Entisols |

* Tentative series

## DESCRIPTIONS OF MAPPING UNITS

### CRB Cuevoland Variant-Ruidoso-Deama Complex (1-8% Slopes)

This inextensive complex occurs in one delineation of Watershed 10A6 in PX Flat at elevations above 6200 feet. Cuevoland variant, Ruidoso, and Deama soils are estimated to comprise 30, 30, and 25 percent, respectively, of the complex. Other soils, mainly those that are too gravelly or too red to be within the defined range of the Cuevoland variant and Ruidoso soils and those with a bedrock substratum that are too deep to be within the defined limits of the Deama series, constitute the remainder of the unit. The soils in the complex are in narrow alluvial valleys, on footslopes, and over shallow bedrock.

Cuevoland variant soils differ from the established Cuevoland series by having darker colors somewhat deeper in the profile. The Cuevoland variant has calcareous, dark brown loam surface horizons that vary in thickness from 5 to 8 inches. The subsoil is a calcareous, dark brown loam, or clay loam, that ranges from 16 to 25 inches thick. A lighter colored caliche horizon is at depths that vary from 22 to 32 inches.

The Cuevoland variant soils are moderately permeable and have high available water.

Ruidoso and Deama soils are similar to those described in the discussion of the RRB and the DRD units, respectively.

The Cuevoland variant and Ruidoso soils are susceptible to erosion on the more sloping areas. Gully cutting, when vegetation cover is markedly reduced, or when human or animal traffic is concentrated, can become serious. Deama soils in this slope class are only slightly susceptible to erosion.

### CND Canutio-Nickel Complex (3-20% slopes)

One area of this unit was delineated in an area highly dissected by arroyos on the middle and upper alluvial fan in Watershed 10A6. The complex extends up the incised valley for a short distance into the faulted mountain front. It varies greatly in slope; the sideslopes are much steeper than the overall slope of the fan surface. Active deposition occurs along some of the arroyo floors. Canutio and Nickel soils comprise an estimated 50 and 25 percent, respectively, of the unit. Other soils in the complex include those less gravelly than the two named soils and those with a shallow gypsic horizon. Streamwash in the bottom of the arroyos constitutes a significant part of the unit.

Canutio and Nickel soils are similar to those described in the discussion of the NCB unit.

Erodibility of the Canutio and Nickel soils is moderate to slight depending on slope, coarse fragment content, and vegetative cover. Vegetative cover is generally sparse. Both are susceptible to gully cutting where traffic is concentrated.

### DRD Deama-Rock Outcrop-Flume* Complex (5-20% slopes)

This complex is relatively inextensive overall, but is of moderate extent in Watershed 1. It is on south and west aspects above 7000 feet.

Deama soils, developed mostly in limestone residuum and slope colluvium, comprise an estimated 30 percent of the unit. They have surface horizons that are calcareous, dark grayish brown to very dark brown, gravelly clay loams or loams. They range in thickness from 2 to 7 inches. The calcareous subsoils, varying from 3 to 18 inches thick, are very dark grayish brown to dark brown, gravelly or very gravelly, clay loams. Sometimes the surface horizon lies directly over bedrock. The soil-bedrock boundary is usually abrupt and irregular.

Deama soils are moderately permeable but have a low water-holding capacity because of their thinness and high content of coarse fragments. However, soil in the bedrock crevices and solution channels increases the available water somewhat.

Rock outcrop makes up an estimated 30 percent of the unit. Where it occurs as horizontally bedded to slightly dipping resistant limestone a "stepped" topography results.

Flume soils, derived mostly from limestone residuum and slope colluvium, make up an estimated 30 percent of the unit. They have noncalcareous, very dark grayish brown or very dark brown, gravelly or very gravelly heavy loam, or thick clay loam, surface horizons that range from 2 to 4 inches thick. The subsoil is usually a noncalcareous very dark grayish or dark brown heavy clay loam that ranges in thickness from 3 to 12 inches. Flume soils are moderately to slowly permeable and have a low to very low water-holding capacity because of their thinness and coarse fragment content. Soil in the bedrock fractures and solution channels probably increases the available water somewhat.

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* Tentative series

Other soils, mostly those slightly deeper than the range permitted for Ector and Flume over bedrock and those in narrow valleys, comprise the remainder of the unit. The "stepped" topography, along with the high coarse fragment and vegetative cover, reduces erosion below that expected on such slopes; nevertheless, the complex is susceptible to increased erosion if use pressure were to radically increase.

### DRF Deama-Rock Outcrop-Flume* Complex (20-50% slopes)

This complex is moderately extensive in Watersheds 1 and 10A6 on very steep slopes. It is mostly on south and west aspects at elevations above 6800 feet. Deama and Flume soils comprise an estimated 30 and 25 percent, respectively, of the unit. Rock Outcrop constitutes an estimated 30 percent. The remainder of the complex is made up of soils deeper than the range permitted for Deama and Flume over bedrock and those in narrow valleys.

Characteristics of the Deama and Flume soils are the same as those described in the discussion of the DRD unit.

The horizontal or slightly dipping beds of resistant limestone causes a "stepped" topography, which along with the high coarse fragment and vegetative cover, reduces erosion below that expected on such slopes. However, the complex is subject to increased erosion if use pressure markedly increases.

### DRG Deama-Rock Outcrop Complex (40-50% slopes)

This extremely rough complex is moderately extensive in Watershed 1 and inextensive in Watershed 10A6 above 6000 feet. Both Deama soils and Rock Outcrop constitute an estimated 40 percent of the unit. The remainder consists mostly of Flume soils and extremely shallow unnamed soils over bedrock.

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* Tentative series

Characteristics of Deama soils are the same as those described in the discussion of the DRD unit.

Runoff is very rapid from the unit. It is mostly inaccessible, but would be subject to accelerated erosion if use pressure were to increase markedly.

## ECF Ector-Rock Outcrop Complex (20-50% slopes)

This complex is inextensive, occurring in canyons above 6200 feet on very steep west aspects in Watershed 10A6. Ector soils and Rock Outcrop are each estimated to comprise about 40% of the association. Other soils, including Flume, occupy the remaining area.

Characteristics of the Ector soils are the same as those described in the discussion of the ERD unit.

The topography is generally "stepped" because of the horizontally bedded or slightly dipping resistant limestone beds. The resultant ledges, along with the high coarse fragment and vegetative cover, reduce erosion below that expected on such steep slopes. However, the association would be subject to increased erosion if use pressure were to markedly increase.

## ERD Ector-Rock Outcrop-Flume* Complex (5-30% slopes)

This complex is moderately extensive on steep south and west aspects at elevations between 5000 and 6800 feet in Watersheds 1, 6, and 7.

Ector soils, which make up an estimated 30 percent of the units, have very dark grayish brown gravelly or very gravelly clay loam, or loam, surface horizons that range in thickness from 2 to 6 inches. Subsoil horizons are dark grayish brown or brown very gravelly clay loams or loams. They range in thickness from 3 to 15 inches. Ector soils are moderately permeable but have a low or very low water-holding capacity because of their thinness and coarse fragment content. Infiltration rates are generally moderate. The subsoil-bedrock boundary is often abrupt and irregular. However, soil in the bedrock fractures and solution channels likely increases the available water slightly.

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* Tentative series

Rock outcrop, comprising an estimated 30 percent of the units, occurs mostly as horizontally bedded to slightly dipping resistant limestone. The resulting "stepped" topography is less erodible than the average slope class suggests.

Flume soils, which make up an estimated 30 percent of the units have noncalcareous very dark grayish brown or very dark brown gravelly or very gravelly heavy loam, or light clay loam, surface horizons that range in thickness from 2 to 4 inches. Subsoil horizons are dark grayish brown or dark brown, noncalcareous, gravelly or very gravelly clay loams. It may be calcareous in the lower part. The subsoil, ranging in thickness from 3 to 15 inches shows a marked increase in clay compared to the overlying surface horizon. Flume soils are moderately to slowly permeable and have a low to very low water-holding capacity because of their thinness and coarse fragment content. Soil in the bedrock fractures and solution channels likely increases the available water somewhat. The subsoil-bedrock boundary is abrupt and often irregular.

Other soils, mostly those too deep or too shallow to be within the range of Ector and Flume comprise the remainder of the area.

Both Ector and Flume soils are relatively stable because of their high coarse fragment and vegetative cover; nevertheless, they are subject to increased erosion if use pressure markedly increases.

## ERF Ector-Rock Outcrop-Flume* Complex (20-50% slopes)

This complex is very extensive on very steep south and west aspects between 5000 and 6800 feet in Watersheds 1, 6, 7, and 10A6. Ector and Flume soils comprise an estimated 35 and 20 percent, respectively, of the unit. Rock outcrop makes up an estimated 35 percent. Other soils, mostly those too deep or too shallow to be within the range of Ector and Flume soils, comprise the remainder of the complex.

Characteristics of the Ector and Flume soils are the same as those described for the ECD unit.

The resistant limestone, where it occurs in horizontal or slightly dipping beds, results in a "stepped" topography. The resultant ledges effectively reduce erosion below that expected on such steep slopes. Also, the high coarse fragment and vegetative cover further reduces erosion. Nevertheless, the complex would be subject to increased erosion if use pressure markedly increases.

### FDD Flume*-Rock Outcrop-Deama Complex (5-30% slopes)

This complex, mostly above 6500 feet, is extensive in Watershed 1 and inextensive in Watersheds 6 and 7. It is mostly on north and east aspects. Flume and Deama soils are estimated to comprise 40 and 20 percent, respectively, of the unit. Rock Outcrop makes up an estimated 25 percent. Other soils, mostly those too deep or too thin (over bedrock), along with some soils associated with the narrow ravines make up the remainder of the complex.

Flume soils, developed in limestone residuum and slope colluvium, have noncalcareous dark grayish brown or very dark brown, gravelly or very gravelly, heavy loam or clay loam surface horizons that range in thickness from 2 to 4 inches. Subsoil horizons, ranging in thickness from 3 to 18 inches, are dark grayish brown or dark brown, noncalcareous, gravelly or very gravelly, heavy clay loams. They are calcareous in the lower part. The upper subsoil has an appreciable increase in clay relative to the overlying horizon. The subsoil-bedrock boundary is usually abrupt and irregular. Flume soils are moderately to slowly permeable and have low to very low available water because of their thinness and high coarse fragment content.

Deama soils, also developed in limestone residuum and slope colluvium, have calcareous, dark grayish brown to very dark brown, gravelly heavy loam or clay loam surface horizons. They range in thickness from 2 to 7 inches. The calcareous subsoils, ranging from 3 to 18 inches thick, are dark grayish brown to dark brown, gravelly or very gravelly clay loams. The subsoil-bedrock boundary is usually abrupt and irregular.

Deama soils are moderately permeable but have low to very low available water because of their thinness and high coarse fragment content. However, soil in the bedrock crevices and solution channels increases the available water somewhat.

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* Tentative series

Where the rock outcrop occurs as horizontally bedded or slightly dipping limestone a "stepped" topography results. The "stepped" surface, together with the high coarse fragment and vegetative cover of the soil surface, reduces erosion below that expected on such slopes. Still, the complex is susceptible to increased erosion if use pressure were to markedly increase.

## FDF Flume*-Rock Outcrop-Deama Complex (20-50% slopes)

This complex, mostly above 6400 feet, is extensive in Watersheds 1, 6, and 7. Where it occurs at lower elevations it is usually on very steep north and east aspects. At higher elevations it tends to occur on the south and west aspects. Flume and Deama soils are estimated to constitute 35 and 20 percent, respectively, of the complex. Rock Outcrop makes up an estimated 35 percent. Other soils, mostly those too shallow or too deep to be within the range of Flume or Deama, comprise the remainder of the unit.

Characteristics of the Flume and Deama soils are like those described in the discussion of the FDD unit.

The topography is generally "stepped" where horizontally bedded or slightly dipping limestone crops out. However, the "stepped" appearance is not pronounced in areas where massive limestone is the parent rock. The "stepped" surface where present, along with the high cover of coarse fragments and vegetation, reduces erosion below that expected on such steep slopes. However, the complex is subject to accelerated erosion if use pressure were to radically increase.

## FRD Flume*-Rock Outcrop Complex (5-30% slopes)

This complex is extensive on steep slopes with north and east aspects, mostly above 7000 feet, in Watershed 6. Flume soils are estimated to constitute 50 and Rock Outcrop 40 percent, respectively, of the complex. Other soils, including Deama and soils that are too shallow or too deep to be within the limits of Flume, comprise the remainder of the unit.

Characteristics of the Flume soils are the same as those described in the FDD unit discussion.

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* Tentative series

"Stepped" topography results when horizontally bedded or slightly dipping resistant limestone beds are present. The "stepped" surface, together with the high coarse fragment and vegetative cover of the soil surface, reduces erosion below that expected on such slopes. Nevertheless, the association would be susceptible to increased erosion if use pressure were to increase markedly.

## FRF Flume*-Rock Outcrop Complex (20-50% slopes)

This complex is on very steep slopes having generally north and east aspects above 7000 feet in Watershed 6. Flume soils and Rock Outcrop are each estimated to comprise 40 percent of the unit. Other soils, including Deama and soils too shallow or too deep to be within the range of Flume, make up the remainder of the unit.

Characteristics of the Flume soils are the same as those described in the FDD unit discussion.

"Stepped" topography results when horizontally bedded or slightly dipping limestone beds are present. The "stepped" surface, together with the high coarse fragment and vegetative cover of the soil surface, reduces erosion below that expected on such slopes. Nevertheless, the association would be susceptible to increased erosion if use pressure were to increase markedly.

## HCD Holloman-Canutio-Nickel Complex (3-15% slopes)

This complex occurs as one delineation on the intermediate section of the alluvial fan in Watershed 10A6. Considerable dissection caused by numerous arroyos of variable depth is characteristic. Holloman, Canutio, and Nickel soils comprise an estimated 45, 25, and 20 percent, respectively, of the unit. Other soils, mainly those that are too sandy to be within the defined range of the named soils and "gypland" areas, are included in the unit. The "gypland" areas are those that lack a soil cover over the gypsite substratum.

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* Tentative series

Holloman soils have weakly to moderately calcareous surface horizons of brown or yellowish brown loam, or very fine sandy loam, that vary from 1 to 12 inches thick. The substratum is composed of earthy to moderately cemented gypsiferous material that varies from pinkish gray to pale brown.

Holloman soils are moderately permeable but have a very low water-holding capacity.

Canutio and Nickel soils are similar to those described in the discussion of the NCB unit.

Erodibility of the soils in the unit ranges from moderate to high depending on slope, coarse fragment cover, and vegetative cover. Holloman soils are especially susceptible to stripping of the soil cover if appreciably disturbed.

### LOD Lozier-Rock Outcrop Complex (5-30% slopes)

This complex occurs mostly below elevations of 6000 feet in the mountain uplands of Watershed 10A6 in one relatively small delineation. Other smaller areas are also present in the watershed but were too small to delineate. Lozier soils and Rock Outcrop are estimated to constitute 45 and 35 percent, respectively, of the complex. Other soils, mainly those too shallow or too deep (or too dark, e.g. Ector), to be within the limits of the Lozier soil, are included in the remainder of the unit.

Lozier soils, along with most of the included soils, have developed in limestone residuum and slope colluvium.

They have grayish brown to dark brown gravelly, or very gravelly, loam to light clay loam surface horizons that vary from 3 to 6 inches thick. Subsoils, when present, are yellowish brown, or dark yellowish brown, very gravelly, stony loams, or light clay loams, that reach a maximum thickness of 30 inches. (Lozier soils, between rock ledges, are often deeper over bedrock than are commonly described; however, they contain a very high percentage of stones.)

Permeability of Lozier soils is moderate or moderately rapid but available water is low or very low because of their shallow profile and very high coarse fragment content. However, soil in the bedrock crevices increases the available water to some extent.

This association is not as susceptible to erosion as the slope class suggests because of the "stepped" topography and high gravel and rock cover. Vegetative cover is moderate.

### LOF Lozier-Rock Outcrop Complex (20-50% slopes)

This complex is mostly below elevations of 6000 feet in the mountain uplands of Watershed 10A6. There is a tendency for it to occur on west and south aspects, but it is also on north and east aspects at lower elevations. Lozier soils and Rock Outcrop are each estimated to make up 40 percent of the unit. Other soils, mainly those tnat are (1) too shallow or deep, (2) too dark, and (3) noncalcareous in the surface horizon, are included in the remainder of the unit.

Lozier soils are like those described in the discussion of the LOD unit.

This relatively inaccessible association is somewhat less susceptible to erosion than the slope class suggests. Although runoff is very rapid, erosion susceptibility is decreased because of the more resistant bedrock ledges and the very high surface cover of coarse fragments. Vegetative cover is moderate.

### LRD Lozier-Rock Outcrop-Holloman Variant Complex (5-30% slopes)

This complex occurs in two delineations of bedrock outliers in Watershed 10A6. Other small areas of the complex may occur in selected localities along the mountain front in 10A6. Lozier soils, Rock Outcrop, and the Holloman variant make up an estimated 35, 30, and 25 percent, respectively, of the unit. Other soils, mainly those too deep to be within the defined limits of the Lozier soil, comprise the remainder of the complex.

The Holloman variant differs from the Holloman soils as described in the discussion of the HCD unit by having a bedrock substratum and by its content of gravel and stones. It has brown gravelly or stony loam surface horizons that vary from 2 to 12 inches thick over fragmented bedrock. Gypsum in the fragmented bedrock is of eolian origin derived from the gypsum beds and dunes in the bolson on the west.

Lozier soils are like those described in the discussion of the LOD unit.

Bedrock ledges and the amount of coarse fragment cover markedly decrease the erodibility of the unit. Vegetative cover, concentrated between the bedrock ledges, is sparse.

## MIB Mibres-Torrifluvents Complex (0-3% slopes)

This complex, in one delineation, is in a broad flat where the alluvial fan terminates in the bolson floor in Watershed 10A6. Mimbres soils and the Torrifluvents each comprise an estimated 40 percent of the unit. This unit floods in most years. Other soils, mainly those that are too sandy or too dark to be within the defined limits of the named series, occupy the remainder of the delineation.

Mimbres soils have brown or dark yellowish brown, loam or clay loam, surface horizons that range in thickness from 2 to 5 inches. They often are platy in the upper part. The subsoils, varying in thickness from 15 to 40 inches, are dark yellowish brown or strong brown loams, clay loams, or sandy clay loams. The substrata are similar to the subsoil except they are usually slightly lighter in color. Mimbres soils lack a distinct caliche horizon but are calcareous throughout the profile.

The Torrifluvents (a great group in the U.S. soil taxonomy) were designated as a component of the mapping unit because of their pronounced variability. They are more weakly developed than the associated Mimbres soils because of episodic deposition from relatively frequent floods. The surface horizons, varying in thickness from 4 to 12 inches, are brown or dark grayish brown loams, clay loams, or sandy clay loams. The substrata, which immediately underlie the surface soil, are stratified loams, very fine sandy loams, and clay loams. They are usually slightly lighter in color than the surface horizons.

Erodibility of the unit is slight as long as good vegetative cover is maintained. Vegetative cover is easier to maintain than in most soils of the area because of the flood water received. However, once destroyed, vegetation is often difficult to reestablish because of a platy crust in the upper part of the surface soil.

## NCB Nickel-Canutio Complex (1-5% slopes)

This complex is on the fan piedmont of Watershed 10A6. Nickel and Canutio soils are estimated to constitute 50 and 25 percent, respectively, of the unit. Other soils, principally those that are more sandy and those having a gypsic substratum, make up the remainder of the complex.

Nickel soils have brown, gravelly or very gravelly, sandy loam or loam, surface horizons that vary from 2 to 4 inches in thickness. Subsoils range from brown to grayish brown, gravelly or very gravelly, loams or sandy loams that range in thickness from 4 to 12 inches. The substratum is a weakly to moderately cemented, very gravelly caliche. Nickel soils are strongly calcareous throughout the profile.

The weakly developed Canutio soils are on young geomorphic surfaces; some areas still receive sediments during prolonged periods of excessive rainfall. They have dark grayish brown or brown gravelly, very gravelly, or cobbly, sandy loam or loam surface horizons that range in thickness from 5 to 11 inches. They overlie a pale brown or brown, gravelly or cobbly, substratum. The coarse fragments may constitute as much as 75 percent of the substratum volume. Canutio soils are strongly calcareous throughout the profile.

Permeability ranges from moderate (mostly Nickel) to rapid (mostly Canutio). Available water is low or very low because of the high coarse fragment content.

Erodibility of the soils ranges from moderate to slight. Those having only a low cover of coarse fragments and sparse vegetative cover are susceptible to both rill and gully erosion. If use pressure were to increase markedly, more erosion would undoubtedly result.

## NCD Nickel-Canutio Complex (5-20% slopes)

This complex occurs on the upper slopes of the alluvial fan of Watershed 10A6 in one relatively large delineation. The surface is rough because of dissection by numerous arroyos. Moreover, it is partially covered with large boulders near the mountain front. Nickel and Canutio soils are estimated to comprise 45 and 30 percent, respectively, of the unit. Other soils, mainly those with an indurated caliche horizon and those overlying gypsic substrata, make up the remainder of the unit.

Erodibility of the soils ranges from moderate to high depending on slope and coarse fragment cover. Vegetative cover is relatively sparse except where the surface is bouldery.

## ORD Sombordoro-Rock Outcrop Complex (5-30% slopes)

This complex occurs in one small delineation in Watershed 1. Sombordoro soils and Rock Outcrop constitute an estimated 45 and 35 percent, respectively, of the unit. Other soils, mostly those too thin or too deep to be within the limits of Sombordoro, make up the remainder of the unit.

Sombordoro soils, developed in sandstone residuum, have very dark grayish brown, gravelly or stony, fine sandy loam surface horizons that range in thickness from 3 to 6 inches. This horizon overlies a lighter colored (brown), gravelly or stony, fine sandy loam horizon that is from 3 to 12 inches thick. The subsoil is dark brown or dark reddish brown, stony sandy clay loam or sandy clay that ranges in thickness from 12 to 30 inches. The substratum is bedded sandstone. The subsoil often extends deep into crevices of the sandstone substratum.

Runoff and erosion are somewhat less than the slope would indicate because of the "stepped" sandstone outcrops together with the high surface cover of coarse fragments and vegetation.

## PAB Penasco Soils (0-3% slopes)

This unit is on gentle slopes on the divides between the arroyos in Watershed 8B-8D. The soils have developed from alluvium on a stable surface of a fan piedmont. Penasco soils are estimated to make up 75 percent of the unit. Included soils are those that are too deep to be within the defined limits of the Penasco series or those that do not have an indurated caliche horizon in the substratum.

Penasco soils have very dark grayish brown, gravelly or cobbly, loam or light clay loam, surface horizons that range in thickness from 6 to 10 inches. They overlie a thin horizon composed of a mixture of gravelly loam and indurated caliche (petrocalcic horizon) fragments. A gray strongly cemented (petrocalcic) horizon, which is laminated on the upper surface, is at depths ranging from 10 to 15 inches.

Permeability is moderate but available water capacity is low because of the shallow depth at which the petrocalcic horizon occurs.

Susceptibility to erosion is minimal because of the gentle slopes and coarse fragment content. Still, "scouring" down to the petrocalcic horizon can occur if traffic is allowed to concentrate on the sideslopes under increased use pressure.

PCB Pajarito-Canutio Complex (1-5% slopes)

This complex occurs in one delineation near the foot of the alluvial fan. Pajarito and Canutio soils comprise an estimated 45 and 35 percent, respectively, of the unit. Other soils, mainly those that are too loamy or too sandy to be within the defined limits of the named soils, are inclusions.

Pajarito soils have surface horizons of reddish brown to dark brown, loamy fine sand or fine sandy loam, that range in thickness from 4 to 7 inches. The subsoil is yellowish red or reddish brown fine sandy loam that ranges from 12 to 20 inches thick. The substratum is very similar to the subsoil except that it usually has a slight accumulation of calcium carbonate. The soil is calcareous throughout the profile. The absence of a well-developed caliche horizon indicates that Pajarito soils are on relatively young geomorphic surfaces.

Canutio soils are like those described in the discussion of the NCB unit.

Pajarito soils have moderately rapid permeability and moderately high available water. They are highly susceptible to both wind and water erosion when the vegetative cover is markedly reduced.

PIB Pajarito-Bluepoint Complex (1-5% slopes)

This unit, occurring in one delineation, is at the foot of the alluvial fan. Most of the parent sediments have been wind reworked. Pajarito and Bluepoint soils comprise an estimated 45 and 35 percent, respectively, of the complex. Other soils, mainly those that are too gravelly (Canutio) or too loamy, make up the remainder of the unit.

Pajarito soils are like those described in the discussion of the PCB unit. They occupy the area between the ubiquitous coppice dunes.

The weakly-developed Bluepoint soils occupy the coppice dunes. They have reddish brown or brown fine sand or loamy fine sand surface horizons that vary from 3 to 10 inches thick. The substrata, often stratified fine sand and loamy fine sand, are slightly lighter in color. The Bluepoint soils are strongly calcareous throughout the profile.

Bluepoint soils are rapidly permeable and have a low available water supplying capacity.

The soils in the association are very susceptible to wind erosion. Erosion rapidly accelerates when the sparse plant cover is disturbed.

### PND Pena-Penasco Complex (5-20% slopes)

This complex occurs in Watersheds 6, 8B, 8D, and 7. It occupies footslopes and stable remnants of dissected alluvial fans. The complex is inextensive in Watershed 6, but is of moderate extent in Watersheds 7, 8B and 8D. Pena and Penasco soils are each estimated to comprise 40 percent of the unit. Other soils included are those in which bedrock occurs at depths less than three feet and those too red (in Watershed 7) to be within the described limits of the two named soils.

Pena and Penasco soils are similar to those described in the discussion of the RRB and PAB units, respectively, except they are generally more sloping.

The association is not as susceptible to erosion as the slope would indicate because of the gravelly nature of the two named soils. However, some of the less gravelly included soils may be subject to gully cutting. Moreover, there is a tendency for shallow soils over a petrocalcic horizon, even on moderate slopes, to "scour" down to the cemented layer when subjected to heavy animal or human traffic.

### PPB Pena-Penasco-Fluventic Haplustolls Association (0-3% slopes)

This association was delineated only on the floor (including terraces) of McKittrick Canyon (Watershed 6). It is inextensive but is very important from the standpoint of potential use. Pena and Penasco soils, and the Fluventic Haplustolls occupy 40, 25, and 20 percent, respectively, of the area. Pena and Penasco soils occupy the low terraces. The Haplustolls are on the floodplain and are subject to frequent flooding. Pena soils may be flooded during periods of excessive rainfall. Cobbly streamwash and other soils outside the defined limits of the named soils occupy the remainder of the delineation.

Pena and Penasco soils are similar to those described in the discussion of the RRB and the PAB units, respectively.

Fluventic Haplustolls (a subgroup in the U.S. soil taxonomy) were mapped instead of a series because of their diversity. They are weakly developed because of episodic deposition due to frequent flooding. The surface horizon, varying from 12 to 18 inches thick, is very dark grayish brown, or dark brown, very gravelly loam or sandy loam. Cobbly loams and sandy loams also occur. The surface horizon directly overlies cobbly, or very gravelly, dark brown or dark grayish brown substrata. The soil is strongly calcareous throughout.

The Fluventic Haplustolls have moderately rapid or rapid permeabilities. Available water capacity is generally low.

The unit does not erode readily because of the low slope gradient and gravelly nature of the soils. However, greatly increased use, which is probable because of its location, could cause erosion on the more sloping areas.

## RPG Rock Outcrop-Deama Complex (40-50% slopes)

This complex is on extremely steep slopes in Watershed 6 between elevations of 5000 and 7500 feet. It is most extensive on north and east aspects because of the natural dissection pattern of the watershed. It occurs less commonly on south and west aspects. Rock Outcrop and Flume soils are estimated to comprise 50 and 35 percent, respectively, of the unit. Other soils, including Flume and soils too shallow or too deep to be within the range of Deama, constitute the remainder of the unit. Flume soils can be expected in pockets among the bedrock outcrops that receive runoff water from the outcrops.

Characteristics of the Deama soils are the same as those described for the DRD unit.

The association is mostly inaccessible because of the extremely rough topography and steep slopes. Runoff from the association is extremely rapid. Erosion could accelerate greatly if use pressure were to increase appreciably.

RRB Remunda-Ruidoso-Pena Complex (0-5% slopes)

This complex is inextensive but is locally important in Watersheds 1, 7, 8B-8D, and 10A6. The complex is on valley floors, narrow stream terraces, and footslopes. Ravines are deeply incised in parts of this unit in Watershed 1. Remunda, Ruidoso, and Pena soils are estimated to comprise 30, 30, and 20 percent, respectively, of the complex. Individual delineations vary considerably in composition. The remainder of the unit is made up of other soils that are outside the range of the three named soils.

Remunda soils have very dark grayish brown or brown loam, or clay loam, noncalcareous, surface horizons varying from 12 to 18 inches in thickness. Subsoils are thick (> 36 inches), dark brown sandy clay loams or sandy clays. They are generally noncalcareous in the upper 20 inches.

Both Remunda and Ruidoso soils are moderately slowly or slowly permeable. Available water is high.

Pena soils have thick (10-14 inches) very dark brown or dark brown, calcareous, gravelly or very gravelly, loam surface horizons. They have dark brown, cobbly or very cobbly, strongly calcareous, loam subsoils that are moderately thick. The substrata are very gravelly loams. (Often, insufficient fine particles are present to fill interstices between the coarse fragments.) A weakly to moderately cemented caliche horizon is usually present in the substratum. Pena soils have developed in much coarser sediments and seem to be on younger surfaces than Remunda and Ruidoso soils. Some areas of Pena soils are subject to flooding during periods of excessive rainfall.

Pena soils are rapidly permeable and have a low available water capacity.

Included among soils in the unit is a Sombordoro variant in the "Bowl" area. (Sombordoro soils, as described in the ORD unit, overlie sandstone, whereas the variant has developed in sandy sediments.)

Other inclusions are similar to Remunda and Ruidoso except they have limestone bedrock within three feet of the surface. The soils of the unit often have a 1- to 2-inch layer of organic litter on the surface.

Runoff from the unit is very slow to medium. Remunda and Ruidoso soils on steeper slopes are subject to gully cutting under heavy use.

### TRD Travessilla-Rock Outcrop Complex (5-30% slopes)

This unit occurs in areas sufficiently large to delineate only in Watershed 7. Travessilla and Rock Outcrop constitute an estimated 50 and 35 percent, respectively, of the complex. Other soils, mostly those too deep to be within the limits of the Travessilla series, comprise the remainder of the unit.

Travessilla soils, developed in thinly bedded sandstone, have calcareous, dark grayish brown, or brown, fine sandy loam or loam surface horizons. They are usually less than 6 inches thick and contain many, large, soft sandstone flags. A subsoil, much like the surface horizon except that it is slightly lighter in color, may or may not be present.

Erosion, although potentially significant on the deeper included soils, is not pronounced at present because of the high coarse fragment surface cover.

## EFFECTS OF ASPECT AND ELEVATION

## PREVIOUS WORK

### Effect of Aspect and Elevation on Soil Temperature

Shreve (1924a) and Cantlon (1953), among others, concluded that, in general, north-facing slopes (north aspects) may differ from adjoining south-facing slopes (south aspects) in various environmental parameters such as soil and air temperatures, soil and atmospheric moisture, light intensity, and wind velocity. Furthermore, these exposure-induced variations were found to cause differences in vegetation.

Shreve (1924a) in his Arizona study concluded that soil temperatures decreased with increased elevation, and that soil temperatures were higher on south aspects than on north aspects. This phenomenon has been confirmed by several other researchers (McDole and Fosberg, 1974; Smith, et al., 1964). In both of the latter studies it was also reported that mean annual soil temperature (MAST) was directly related to elevation.

A.W. Cooper (1960) in a Michigan study explained the role of micro-climate in soil genesis with emphasis on topographical location. Light intensity was always highest on south aspects during every season. The greatest difference in maximum air temperatures occurred during midsummer. Differences in average minimum air temperatures were greatest during the growing season and were smallest during the winter months. In early spring, before canopy closure, lowest minimum air temperatures were found on north-facing slopes. Throughout the entire growing season, evaporation losses were greater on south aspects, while more favorable soil moisture levels obtained on north aspects. Cooper's (1960) study also correlated aboveground climate and underground soil temperatures. He also concluded, as did Jenny (1941), that it was soil temperature and moisture conditions of a soil through time, that were of most importance in soil genesis occurring on opposing slopes.

Smith, et al. (1964) concluded that groundwater and organic matter had little influence on MAST, but that shallow groundwater did influence seasonal temperature fluctuations during periods of freezing and thawing.

Franzmeier, et al. (1969) reported temperature differences between north- and south-facing slopes due to differences in the amount of solar radiation received on the Cumberland Plateau of Tennessee. North aspects had greater variation in soil temperatures than did south aspects, and temperature differences due to aspect were greater in winter than in summer.

Apparently, the effects of direct radiation on soil temperatures are greatly modified by diffuse radiation, air temperatures and air movement, and evapotranspiration of soil water (Franzmeier, et al., 1969; Fluker, 1958).

According to Smith, et al. (1964), mean monthly soil temperatures vary with depth. In any given soil, temperature fluctuations are greater with proximity to the surface. Seasonal variations of soil temperature are also greatest at the surface and tend to decrease with depth until, at a depth of 30 feet or more, they disappear.

Smith, et al. (1964) indicated that mean monthly soil temperature, at prescribed depths, fluctuated about the MAST as an approximate sine curve, showing fluctuations at the 9-m (30-foot) depth, to be less than 0.1C (0.2F). This, they concluded, allowed an estimation of MAST values to be accomplished by a single reading taken at 9-m any time throughout the year. McDole and Fosberg (1974) had similar results in Idaho and concluded that soil temperatures vary with depth due to daily and seasonal cycles. Several researchers found that daily soil temperature fluctuations are minor below the 50-cm (20-inch depth (Elford and Shaw, 1960; Smith, et al., 1964).

Vegetative cover and litter accumulation are generally thicker in colder climates. Thus, they reduce seasonal fluctuations of soil temperature because of insulation effects (Smith, et al., 1964).

Bouyoucos (1916) found that coarse-textured soils are warmer than fine-textured soils because they hold less water for evaporation and hence have less cooling potential. However, he concluded that soil color and texture generally had minor effects on MAST. Other research agrees with these conclusions (McDole and Fosberg, 1974; Smith, et al., 1964).

Carlton, et al. (1974) showed in their New Mexico study, that soil temperatures occurring at higher elevations tended to be warmer on southern exposures than on northern exposures. They described natural vegetation zones and the elevations at which they occurred, and noticed temperature differences among various sites as influenced by wind speed and direction, and amount of snow cover.

Daubenmire (1968) concluded that litter accumulation reduced soil temperatures. In cool climates, soil temperatures under dense vegetation tended to be lower in spring and summer, but higher in autumn. A forest canopy tended to shift the favorable temperature period for plants to later in the annual rainfall and photoperiod cycles due to the ability of the canopy to delay alternate freezing and thawing of a soil. Daubenmire concluded that this was one way an overstory can exert control over successional changes. The canopy would also intercept snow and allow the soil to freeze deeper before an insulating blanket could accumulate.

Observations in areas with considerable relief reveal variations in vegetative composition with aspect differences. Gail (1921), in a study of Douglas fir distribution, found that northeast-facing slopes supported forest vegetation while south-facing slopes were treeless. His study revealed that south aspects had greater wind velocities, lower relative humidity, more evaporation, and warmer soil temperatures.

Shreve (1924b) found vegetation to be markedly affected by soil exposure. He concluded that insolation was more important than air temperature in determining soil temperature, and that the differences in vegetation on north- and south-facing slopes were due to a group of conditions initiated by differences in insolation and soil temperature.

## Effects of Soil Temperature, as Influenced by Aspect, on Soil Properties

### Morphological Properties

Soil profiles on contrasting north- and south-facing slopes have been shown to be substantially different in response to different soil forming factors.

Aandahl (1948) stated that when describing a slope position, several factors must be considered. While topography was a major soil forming factor because it influences temperature, runoff, and evapotranspiration, slope gradients were not, in themselves, adequate to completely describe soils occurring on the slope. In addition, slope length, curvature (whether convex or concave), and exposure were also important in soil formation and development.

A.W. Cooper (1960) found that north- and south-facing slopes were characterized by different types of weathering processes. The sola were deeper on the north aspects and shallowest on the upper slopes of south aspects. The fact that the surface horizons of south aspects underwent cycles of freezing and thawing in winter, and periods of alternate wetting and drying during spring and summer, resulted in proportionately greater soil weathering occurring on southern slopes during the year. Cooper explained that similar horizons on north aspects remained uniformly frozen throughout the winter in Michigan. Thus, the physical stresses caused by alternate freezing and thawing, as well as the temperature changes, resulted in greater chemical and biotic weathering on south aspects. He concluded that, in general, microclimates of south-facing slopes favored shallow, intense profile development, whereas that of north-facing slopes produced deeper, less weathered profiles.

Losche, et al. (1970) explained that differences found in weathering stages on north versus south aspects in their North Carolina study were due to higher soil temperatures which occurred on south-facing slopes.

Franzmeier, et al. (1969) found that soils occurring on southern aspects had argillic horizons, while northern exposures had cambic horizons on the Cumberland Plateau. Prior to the study, the investigators hypothesized that soils on steep mountain slopes had thin, weakly developed profiles; however, they found the slopes to be relatively stable, and that soils which had developed from acid shales and siltstone had deep, well-developed sola.

### Physical Properties

Steen (1957) in Germany, found that under a natural pasture with south aspects of 4° and 20°, there was little difference in the well-developed crumb structure in the upper 10-cm of soil. Lower in the profile, soil on south aspects showed a more pronounced fragmented structure with small aggregates and greater pore space. North-facing slopes showed larger aggregates and more available water with less evapotranspiration.

A study by Klemmedson (1964), in Idaho, showed that gravel content on south exposures was greater than on north exposures. The soils studied had developed from Crowsnest Gravel which consisted mostly of quartzite and granite. Gravel content increased with distance downslope, but then again decreased at the bottom. Presumably, the differences in gravel content related to exposure had arisen from differential soil formation and soil erosion. Since there was a flattening of the slope near the bottom, gravel content should have decreased. On north aspects, gravel content was higher on the ridge shoulder, yet decreased with distance downslope to the bottom.

According to Losche, et al. (1970), soils of opposing aspects differed significantly in physical and chemical properties as well as in morphology. South-facing slopes tended to be redder in color and had higher free iron contents. They also found soils on south exposures to have thicker sola, contain more clay in the B horizons, and to show more evidence of clay illuviation. In contrast to what A.W. Cooper (1960) and Aandahl (1948) stated, Losche, et al. (1970), suggested that soils occurring on the lower slope positions were more highly weathered than the soils on the upper slope positions.

Franzmeier, et al. (1969) pointed out that soils on north exposures were darker in color than those of the south aspect. In soils paired for elevation, the A and upper B2 horizons of those on north aspects had lower chromas or lower values than on south aspects. South aspects were found to have redder B horizons. A.W. Cooper (1960) concluded that A1 horizon colors were darker on north aspects as a result of higher organic matter accumulation.

### Chemical Properties

Several researchers have found organic matter to be higher on north-facing slopes than on south-facing slopes (A.W. Cooper, 1960; Finney, et al., 1962; Franzmeier, et al., 1969; Klemmedson, 1964). Franzmeier, et al. (1969) concluded that soils on south aspects had less organic matter throughout their sola because of warmer temperatures, which promoted more rapid oxidation. Northern exposures had greater amounts of litter which persisted longer than on opposing southern exposures. Finney, et al. (1962) showed that organic matter content, expressed as organic carbon percent, did not vary appreciably in the A1 horizons of northeast- and southwest-facing slopes. However, when it was expressed on a weighted basis down to 20 inches it was significantly higher on northeast-facing slopes, due to the greater amounts in subsoil horizons. Klemmedson (1964) found that organic carbon, water retention, and percent nitrogen were greater on north exposures.

In their southern Arizona grassland study, Haase and Schreiber (1972) reported percent vegetative cover varied in response to aspect, soil differences, and slope position. In determining aspect influences on the Bernadino series, they found more acid soils, greater clay contents, and higher moisture retention at 15 atmospheres tension on north aspects, and indicated that this was due to greater leaching. They related this to lower incident radiation on northern slopes.

Steen (1957) stated that soils on south-facing slopes showed higher pH, and contained more soluble phosphorus and potassium which perhaps allowed development of a "Brown" soil, or "Para-Rendzina" under climatic conditions which led to podzolization on north-facing slopes.

### Mineralogical Properties

Losche, et al. (1970), in a study of soils developed from granitic biotite gneiss in a North Carolina study area, found that greater depth of mineral weathering occurred on south-facing slopes. This was possibly due to the higher amounts of annual precipitation, along with increased soil temperatures, in contrast to their Virginia study area. The parent material at the Virginia study location was highly siliceous sandstone and siltstone. Under the higher temperature regime, there was more rapid dissolution of the primary materials. They stated that gibbsite dominated the fine clay fraction of the south aspect soils, while on soils occurring on north slopes, the lower soil temperature regime would slow mineral dissolution, hence altering the mineralogical properties, and kaolinite synthesis and conversion of mica to 2:1-2:2 intergrade minerals would be promoted.

## MATERIALS AND METHODS

Sampling sites were selected in three different watersheds in the Park, based on differences in moisture and temperature regimes (Table 114). Opposing aspects, similar slope gradients and similar elevations were chosen for each pair of sites, resulting in six pedons selected for detailed study.

Location of individual sites selected for detailed soil studies are shown in Figures 101, 103, and 104. South and north aspects (Figures 105 and 106) in Watershed 10A6 (the desert westside) were designated 1S and 1N, respectively. South and north aspects from Watershed 7 were designated as 2S and 2N, respectively; sites and associated pedons are shown in Figures 107-110. South and north aspects from the Bowl area of the McKittrick Canyon Watershed (number

6) were designated 3S and 3N, respectively; sites and associated pedons are shown in Figures 111-114.

TABLE 114. ELEVATION AND ESTIMATED PRECIPITATION AT THE SITES STUDIED

| Site No. | Elevation | Estimated Precipitation |
|---|---|---|
| | meters<br>(feet) | mm<br>(inches) |
| 1 | 1463<br>(4800) | 254<br>(10.0) |
| 2 | 1615<br>(5300) | 533<br>(21.0) |
| 3 | 2385<br>(7825) | 685<br>(27.0) |

## Soil Sampling

Soil pits were hand dug and profiles described according to the system used in the United States (Soil Survey Staff, 1975). Bulk samples were taken from all horizons for laboratory analysis and 35 mm color slides were taken of each soil profile and site. Common plant species were identified at each location. Percent surface stoniness and bedrock outcrop were estimated. Percent slope was determined by use of an Abney hand level.

## Temperature Cell Installation and Measurements

Soil temperatures were taken by use of a Soiltest Model MC302* soil moisture and temperature meter. Model MC 310A temperature/moisture cells with 6-foot leads were buried at 50 cm (20 in) at each sampling location. Pits were dug next to the original pit in which the profile had been described and the cells were implaced to ensure a good soil-to-cell contact. Pits were then filled using the original material and replaced in such a way as to simulate the

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* The use of manufacturers' names is intended solely for specific identification of equipment utilized and does not imply any form of endorsement by Texas Tech University or other agencies involved in this research.

Figure 105. Site 1S. (Watershed 10A6).

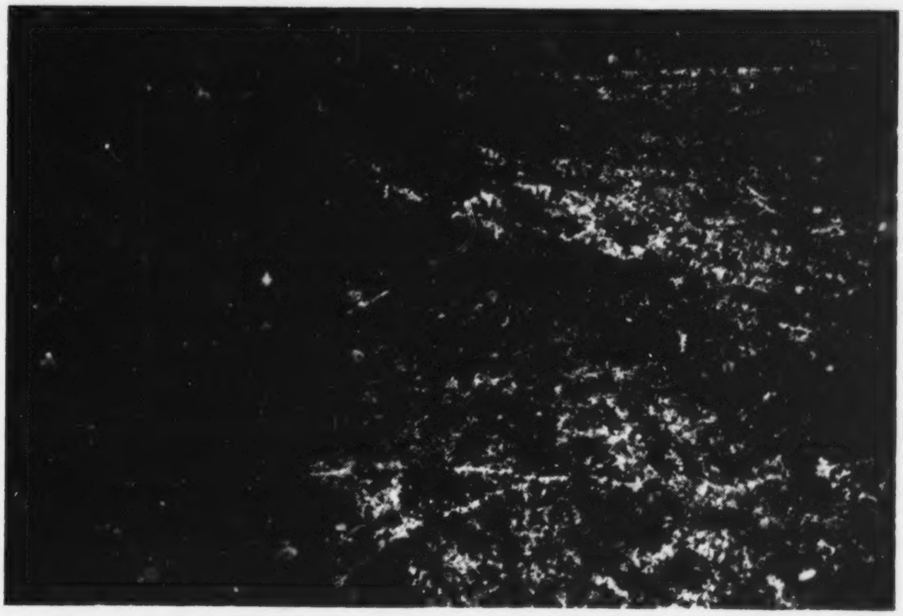


Figure 106. Site 1N. (Watershed 10A6).

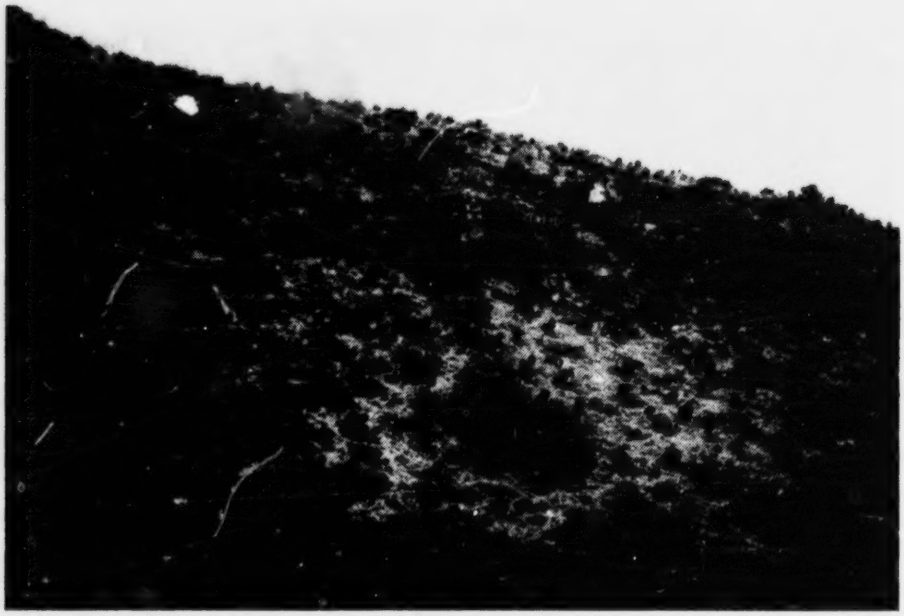


Figure 107. Site 2S. (Watershed 7).

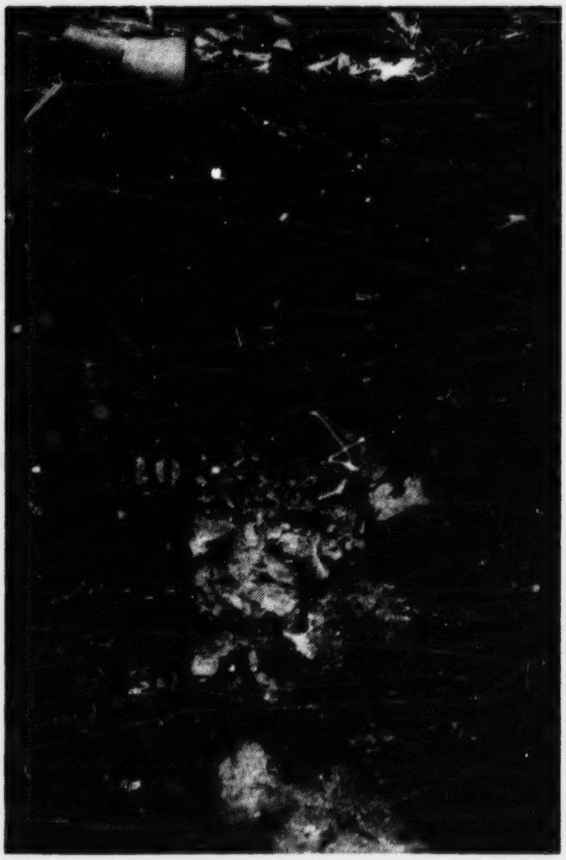


Figure 108. Profile at Site 2S. (Watershed 7).

Figure 109. Site 2N. (Watershed 7).

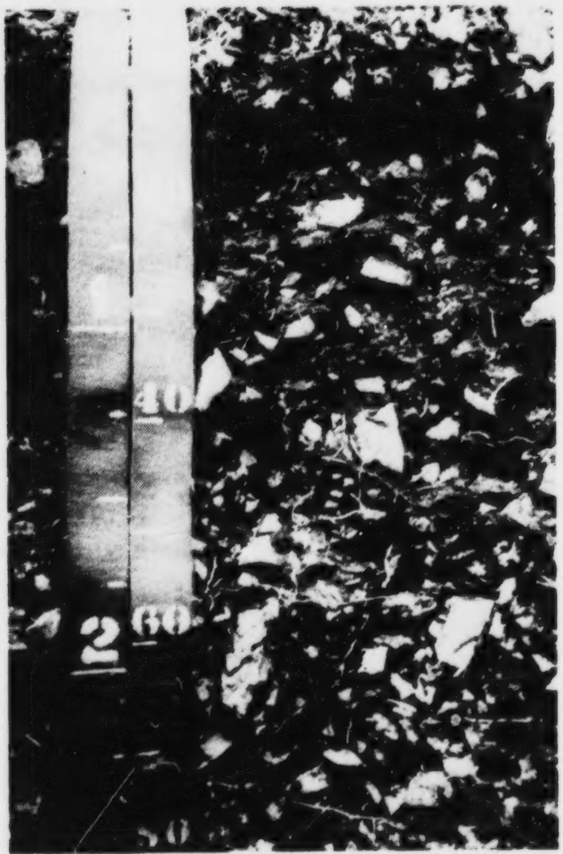


Figure 110. Profile at Site 2N. (Watershed 7).

Figure 111. Site 3S. (Watershed 6).

Figure 112. Profile at Site 3S. (Watershed 6).

Figure 113. Site 3N. (Watershed 7).

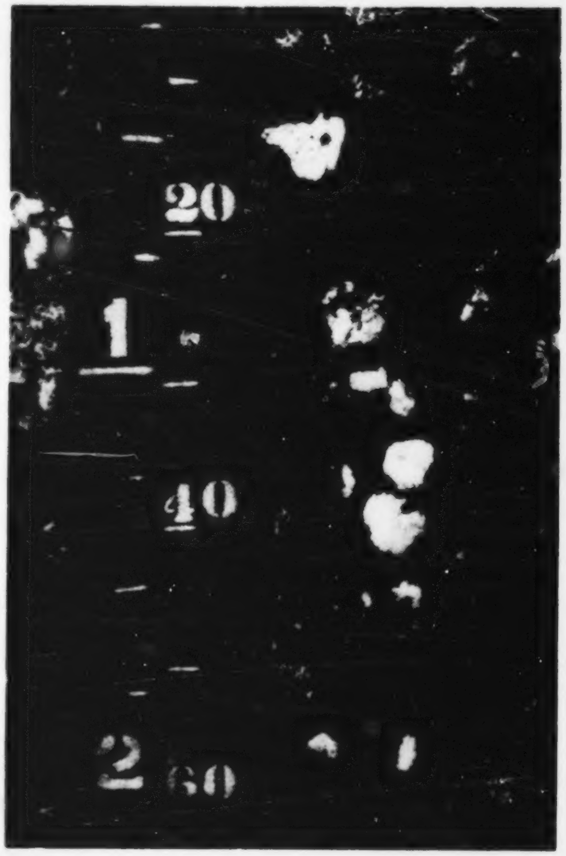


Figure 114. Profile at Site 3N. (Watershed 6).

original compaction. While filling the pits, each temperature cell lead was arranged to prevent water from running directly down the lead to the cell, thus possibly affecting temperature readings.

Monthly temperature readings were taken from July, 1978, through August, 1979. Mean Summer Soil Temperature (MSST) and Mean Winter Soil Temperature (MWST) were determined. Mean Annual Soil Temperature (MAST) was then calculated from the monthly readings, and compared to Mean Seasonal Soil Temperatures (MMST).

### Particle Size Distribution

Particle size distribution was determined on all horizons by a modified version of the hydrometer method as described by Bouyoucos (1916). Deionized water was added to a 50-g sample of soil; the mixture was shaken and brought to a volume of 1000 ml. Clay was determined at the two-hour reading. Sand was determined by wet sieving through a 300-mesh sieve. Silt was determined by difference. Five ml of 10% sodium hexametaphosphate [$Na_6(PO_3)_6$] solution was used as a dispersant.

### Soil Reaction

The pH of a saturated paste of each horizon was determined on a Beckman Expandomatic pH meter. A saturated paste was prepared using approximately 150 g of soil and allowed to equilibrate overnight prior to measurement.

### Electrical Conductivity

Electrical Conductivity (EC) of each horizon was determined using the saturated paste extract (from previous pH determinations) as outlined in USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954).

### Soluble Cations

Soluble cations of each horizon were determined on part of the extract used for the EC measurement. Calcium (Ca) and magnesium (Mg) were analyzed by atomic absorption on a Perkin-Elmer unit, Model 290B. Sodium (Na) and potassium (K) determinations were made by flame emission. Results are expressed in milliequivalents per liter (meq/l).

## Cation Exchange Capacity

Whole soil, fine clay, and coarse clay cation exchange capacities (CEC's) were determined using the procedure outlined in USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954). Displaced $Na^+$ (used to saturate the exchange complexes) was determined by flame emission, using the Coleman, Model 21, flame photometer. All CEC's were calculated from a standard curve prepared from 0,2,4,6,8, and 10 meq/l solutions of sodium chloride (NaCl) in 1 normal (N) ammonium acetate $[NH_4(Ac)]$ adjusted to pH 7.0.

## Organic Carbon

Organic carbon was determined on all horizons sampled by a modified version of the Walkley-Black method. Ground samples were passed through a 60-mesh sieve. Approximately 0.5 g of soil was weighed and transferred to a 300-ml erlenmeyer flask. Exactly 10 ml. of 0.4 N chromic acid ($H_2CR_2O_7$) was added from a burette. Small funnels were placed in the top of the flasks to act as condensers. The soil-acid mixture was then boiled gently for five minutes with occasional swirling to get the soil in suspension. After cooling, deionized water was added to make a volume of approximately 250 ml. Three to 5 ml of concentrated sulfuric acid ($H_2SO_4$) and three drops of orthophenanthroline indicator were added. The samples were then titrated with an approximately 0.2N ferrous ammonium sulfate solution $[Fe(NH_4SO_4)_2.6H_2O]$ to the end point, which was marked by a reddish tinge following a bright green. Acid-washed quartz sand was used as a blank. Percent organic carbon was then calculated using the equation:

$$\frac{(B-U) \times D \times N \times A}{W} \times 100 = \text{Percent organic C}$$

Where:

B = ml $[Fe(NH_4SO_4)_2.6H_2O]$ used for the blank;
U = ml $[Fe(NH_4SO_4)_2.6H_2O]$ used for the sample;

D = ml chromic acid used (10 ml);
N = normality of chromic acid (0.4 N);
A = milliequivalent weight of carbon (0.003);
W = weight of sample used, expressed on oven dry basis.

## Ammonium Acetate Extractable Cations

Ammonium acetate $NH_4(Ac)$ extracts were made in accordance with procedures outlined in USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954). Ca and Mg were determined by atomic absorption; K and Na were determined by flame photometer. Concentrations were converted to milliequivalents per 100 grams (meq/100g).

## Water Saturation Percentage

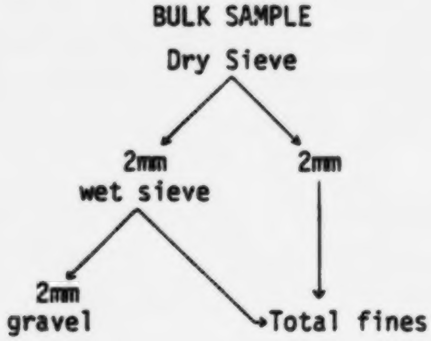
Water saturation was determined on the soil paste by oven drying according to procedures outlined in the USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954). A portion of the saturated paste, prepared for EC and water soluble cation measurements, was used for water saturation percent.

## Water Retention

A pressure membrane apparatus was used to determine water retention at 1/3, 3, and 15 bars tension on all samples taken, by the method described in the USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954). Samples from contrasting profiles at similar elevations were determined simultaneously. This precluded the possibility of differences in pressure taking place during determinations on samples from a single site.

## Coarse Fragment Procedures

Soil bulk samples were air dried and separated to obtain approximately a 1-kg representative sample. Separated samples were dry sieved through a 2-mm sieve and the aggregates were ground. Coarse and fine material were then put in separate containers, and the fines weighed and recorded. Coarse fragments were placed in plastic shaking jars, with 5 ml of 10% $Na_6(PO_3)_6$ solution added for dispersion, the mixture was then brought to volume with deionized water and stoppered. After shaking for 4 hours, coarse fragments were washed and set aside to dry. The washed fine material was wet sieved and then dried in an oven at 105C. Weights were recorded of both coarse fragments and washed fines. The wet sieved fines were then added to dry sieved fines to obtain the total weight of the fine fraction. A schematic diagram depicting separation of coarse and fine fractions is given below:



## Calcium Carbonate

$CaCO_3$ equivalent values of all calcareous horizons were determined by a slightly modified acid neutralization procedure outlined in USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954). Previous experience has shown that iron (Fe) in West Texas soils forms a complex which precipitates and obscures the colorimetric end point. The procedure was modified in that the endpoint was not indicated with phenolphthalein but rather with a Beckman expandomatic pH meter. The endpoint was reached when the solution held a pH of 8 for 30 seconds.

## Qualitative Gypsum Test

The possible presence of gypsum was determined by adding a few drops of barium chloride ($BaCl_2$) to filtrates. The test was performed to determine whether flocculation is likely in particle size distribution analyses and clay separation procedures.

## Clay Separation for X-ray Analysis

Separation of clay fractions for mineralogical study was performed on two selected horizons from each profile. After dispersion of the

$H_2O_2$-treated samples, suspensions were washed into 500-ml erlenmeyer flasks containing 5 ml of 10% Calgon solution, agitated on reciprocating shaker overnight, and then transferred to 1000-ml sedimentation cylinders. The suspensions were brought to volume with deionized water and siphoned with a recurved glass tube at the time calculated by Stokes Law for a 2-micrometer (μm) particle to fall 30 cm. The cylinders were refilled to volume and the siphoning procedure repeated until a negligible amount of clay remained. Volumes were controlled by flocculation with 10% $CaCl_2$ and subsequent decantation. The flocculated clays were dialyzed in deionized water until dispersion occurred and then stored.

## X-Ray Diffraction of Clays

An adequate quantity of clay suspension was placed into a 15-ml conical centrifuge tube and 5 ml of 0.3N $CaCl_2$ was added to ensure $Ca^{+2}$ saturation of the exchange sites. After centrifugation the supernatant liquid was decanted and the procedure repeated twice. Following saturation, the clay was washed with 5 ml of 1% glycerol solution and centrifuged until dispersion occurred. After the final washing, 5 ml of 1% glycerol solution was added to the suspension which was then stirred and pipetted onto a glass slide. After drying, the slide was heated to 60C overnight to remove any excess glycerol.

A similar saturation procedure was followed in preparing K-saturated samples except that 0.3N KCl solution and deionized water were used instead of the $CaCl_2$ and glycerol, respectively. The washed dispersed solution was pipetted onto a glass slide, air dried, and heated to 250C for 4 hours, and X-rayed. After X-raying, the same sample was heated at 550C for 4 hours and then again X-rayed.

Clays were X-rayed on a GE diffractometer using nickel-filtered copper K-$\alpha$radiation measured by a geiger counter. Scanning speed was one degree per minute with the recorder speed set at 2° per inch, and the diffractograms recorded from 2° to 30°2$\theta$. Time constant was 2, and the samples were run at 500 counts per second (cps).

## DISCUSSION OF RESULTS

The soils of the higher elevations of Guadalupe Mountains National Park and the surrounding area, have been developed primarily in residuum from Permian limestones. Characteristically, they are immature, moderately dark in color, and relatively high in organic matter. (Refer to Appendix B for complete profile descriptions.)

In the desert region of the Park (site 1), the infrequent precipitation and high evaporation rates have resulted in the accumulation of salts, primarily $CaSO_4.2H_2O$ (gypsum) and $CaCO_3$ (lime) on the alluvial fans. Some $CaCO_3$ may be blown in, but most is probably formed from dissolution and reprecipitation of $CaCO_3$ from the limestone. These soils are strongly calcareous throughout the profiles, and are medium to coarse textured. Soils in this region are light colored and low in organic carbon.

Field observations revealed distinct morphological differences between soils at the same elevations but on different aspects. Differences also occurred among soils at different elevations but on similar aspects. Of the six pedons studied, only sites 2N, 3S, and 3N in the upper elevations of the park, had enough clay translocation to meet the requirements of an argillic horizon. Sites 3S and 3N were the only pedons that were noncalcareous to weakly calcareous throughout. Site 2N in Watershed 7 was noncalcareous down to an Rca horizon. In sharp contrast, all other study sites were strongly calcareous, and at sites 1N, 1S, and 2S, secondary $CaCO_3$ coatings were apparent on the coarse fragments.

In comparing depth of profile development, north aspects had deeper sola, yet depth to the limestone bedrock was highly variable in each pedon.

Percent vegetative cover showed pronounced variation with respect to opposing aspects as well as elevational differences. North aspects at all three sites had more vegetative cover than opposing south aspects. At pedons 1N and 1S, percent vegetative cover between opposing aspects showed the least apparent difference when compared with the other two sites. North aspects supported slightly greater amount of shrub cover, or trees in the case of 3N, and slightly more grass cover than corresponding south aspects. Increased litter accumulation was evident at sites 2N and 3N. Pedon 2N had considerably more oak cover than pedon 2S. Oak comprised approximately 40 to 50% of the total vegetative cover on the north aspect, but only 5 to 10% on the south aspect. At pedon 3N, Douglas fir, ponderosa pine and oak were the dominant tree species; all were absent on 3S, but alligator juniper was common. These site 3 soils were typically darker colored, higher in organic matter, and had lower pH values (mildly alkaline to slightly acidic) when compared to the other two sites.

Textures differed among the three sites, although gravel content remained relatively high in all cases. In the desert region, textures were medium, while in the mountainous regions, textures were medium and fine. Coarsely fragmented limestone, apparently derived from the underlying bedrock, was high in all pedons. Soil horizons often penetrated deep within the bedrock crevices, causing irregular boundaries to occur. This was especially evident at site 3 where sampling was not possible below large rock boulders with ordinary hand digging equipment, yet Bt material was still present in the cracks.

The lower B2 horizons of sites 1S, 2N, 2S, and 3S had structures described as "rock controlled" because of the high coarse fragment content.

Monthly soil temperatures are listed, along with MAST, MSST, MWST, and MMST in Table 115. The two July readings were averaged in calculating MAST values. For site 1, readings were missed in September 1978 due to impassable muddy roads. At site 2, the December readings were missed due to icy road conditions. In calculating MAST values, missing data points were interpolated from plots of monthly soil temperatures. The missed September reading was estimated by averaging the August and October readings. The same method was employed at site 2, using the January and November readings. Differences in MAST values occurred between opposing aspects at similar elevations, as well as among pedons of similar aspect at different elevations.

All south aspects were warmer than corresponding north aspects throughout the year as reflected by their MAST values (Figures 115-117). Vegetative cover and aspect as it controls direct exposure to sunlight appear to be the most influential environmental parameters affecting soil temperatures at a given elevation.

## TABLE 115. SOIL TEMPERATURE MEASUREMENTS (C) AT 50 cm

| Month | 1S | 1N | 2S | 2N | 3S | 3N |
|---|---|---|---|---|---|---|
| 1978 July | 27.2 | 26.5 | 26.1 | 25.0 | 20.5 | 17.8 |
| Aug | 24.4 | 22.5 | 23.8 | 22.7 | 17.8 | 16.1 |
| Sept | 22.5 | 17.5 | 17.5 | 14.5 | 14.0 | 10.0 |
| Oct | 20.5 | 12.5 | 20.5 | 13.0 | 17.1 | 10.5 |
| Nov | 15.0 | 8.5 | 13.5 | 8.2 | 11.5 | 5.2 |
| Dec | 9.2 | 4.0 | 10.9 | 5.6 | 6.0 | 2.0 |
| 1979 Jan | 8.5 | 3.7 | 8.2 | 3.0 | 5.0 | 1.0 |
| Feb | 12.0 | 4.2 | 11.0 | 4.2 | 7.0 | 2.0 |
| Mar | 16.0 | 8.5 | 15.0 | 8.5 | 10.5 | 4.0 |
| Apr | 19.2 | 12.5 | 18.0 | 12.0 | 14.0 | 8.0 |
| May | 21.5 | 18.0 | 20.0 | 15.0 | 16.0 | 10.0 |
| Jun | 24.2 | 22.5 | 21.5 | 19.0 | 19.0 | 13.0 |
| July | 26.0 | 23.0 | 24.0 | 21.5 | 22.0 | 16.0 |
| MAST | 18.3 | 13.3 | 17.1 | 12.4 | 13.2 | 8.2 |
| MSST | 25.1 | 23.2 | 23.5 | 21.7 | 19.4 | 15.3 |
| NWST | 9.9 | 3.9 | 9.6 | 3.6 | 6.0 | 1.7 |
| NMST | 18.8 | 13.4 | 17.9 | 12.8 | 14.3 | 9.0 |

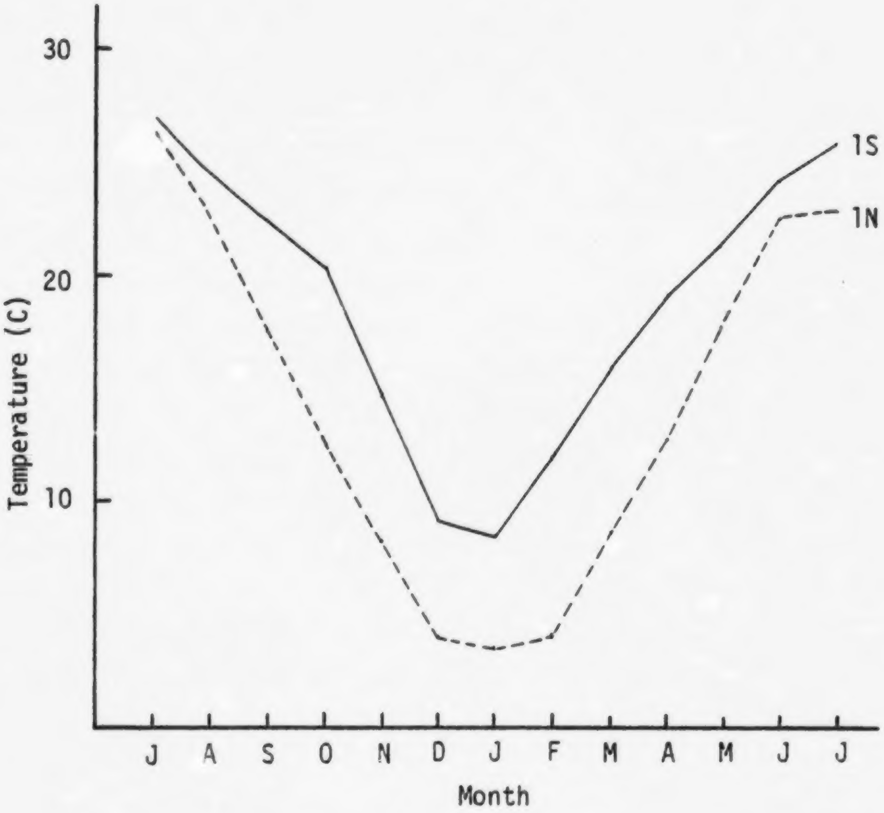


Figure 115. Monthly Soil Temperatures at Site 1. (Watershed 10A6).

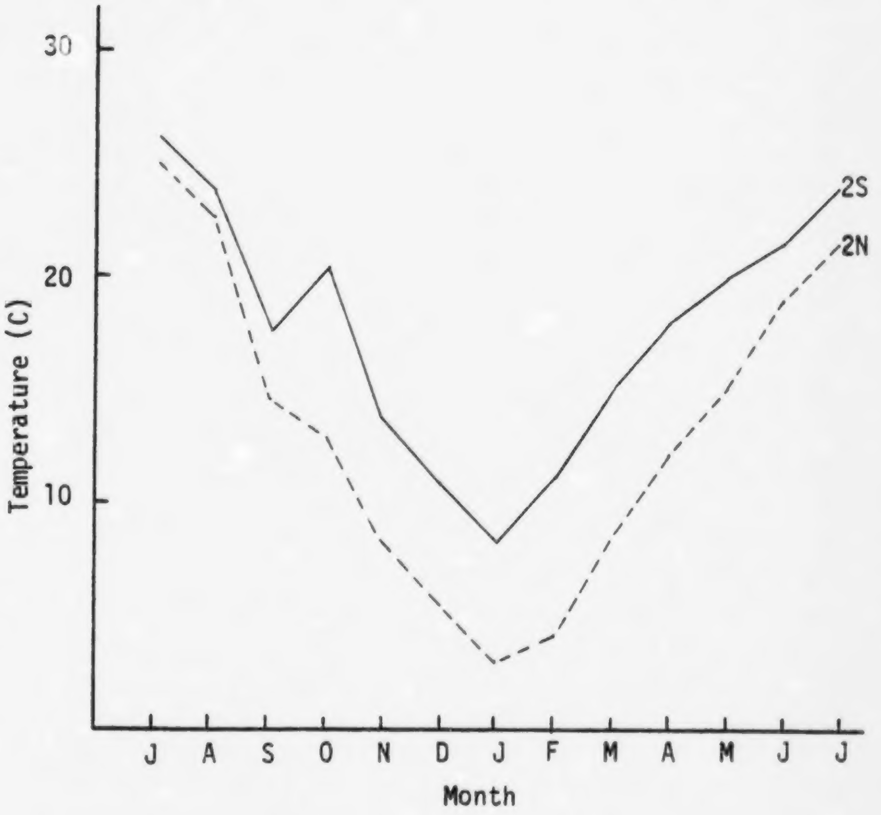


Figure 116. Monthly Soil Temperatures at Site 2. (Watershed 7).

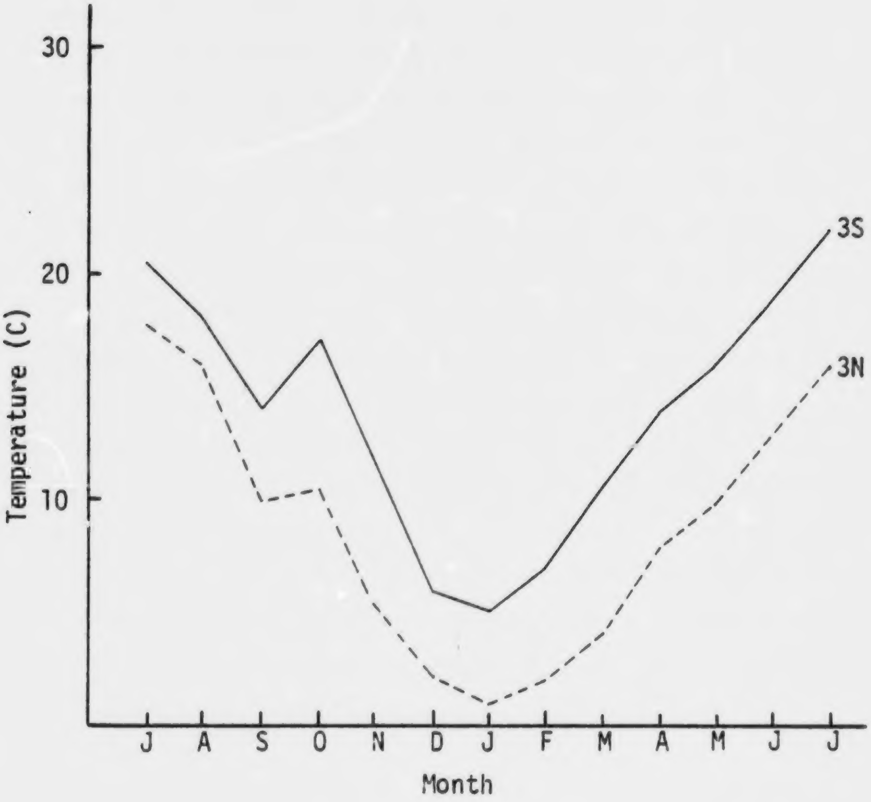


Figure 117. Monthly Soil Temperatures at Site 3. (Watershed 6).

Soil temperature variations due to differences in elevation fell on predicted trends on both south and north aspects (Figures 118-119). However, the difference between MAST values for corresponding aspects at sites 1 and 2 was unexpectedly low and could not be explained.

Soil temperature regimes were tentatively designated from MAST values obtained from measurements made for 13 months. The MAST values of pedons 1S and 2S show them to be thermic with temperatures of 18.3C and 17.1C, respectively. The MAST values of pedons 1N, 2N, 3N, and 3S were 13.3C, 12.4C, 8.2C and 13.2C, respectively, indicating a mesic regime. At the beginning of the study, it was believed that the MAST of site 3N would qualify it as being in the frigid temperature regime since it is above 2300 m and supports a ponderosa pine-Douglas fir community. Yet upon analyzing the data collected for 13 months, the MAST indicated a mesic regime. One possible explanation may be that the location of the Park is too far south to warrant the 8C limit for the frigid regime, whereas similar elevations slightly further north would probably be in that regime. Additional data may indicate the need to adjust these initial temperature regime designations.

Particle size distribution studies showed a range of medium (silt loam) to fine (clay) textures (Table 116). Profiles 1S and 1N, all loams and gravelly loams, showed very little difference in clay content. Due to their high $CaCO_3$ content, clay translocation in the profile would not be expected. There seemed to be very little difference in textures due largely to low weathering intensity differences, between the two opposing aspects. Silt contents were relatively high because of eolian contributions. Sand contents were the highest of all sites and were probably influenced by strongly aggregated sand size $CaCO_3$.

Profiles 2S and 2N showed greater differences in percent clay than between pedons on opposing aspects at the other two study sites. Profile 2N showed appreciably more clay, probably because of a higher moisture status. Clay translocation had occurred sufficiently to qualify the profile as having an argillic horizon. Sand contents of both profiles were the lowest found of all three sampling locations. In contrast to sites 1S and 1N, sites 2S and 2N showed a definite elevation influence that distinguished them from the lower and less weathered profiles in the desert region.

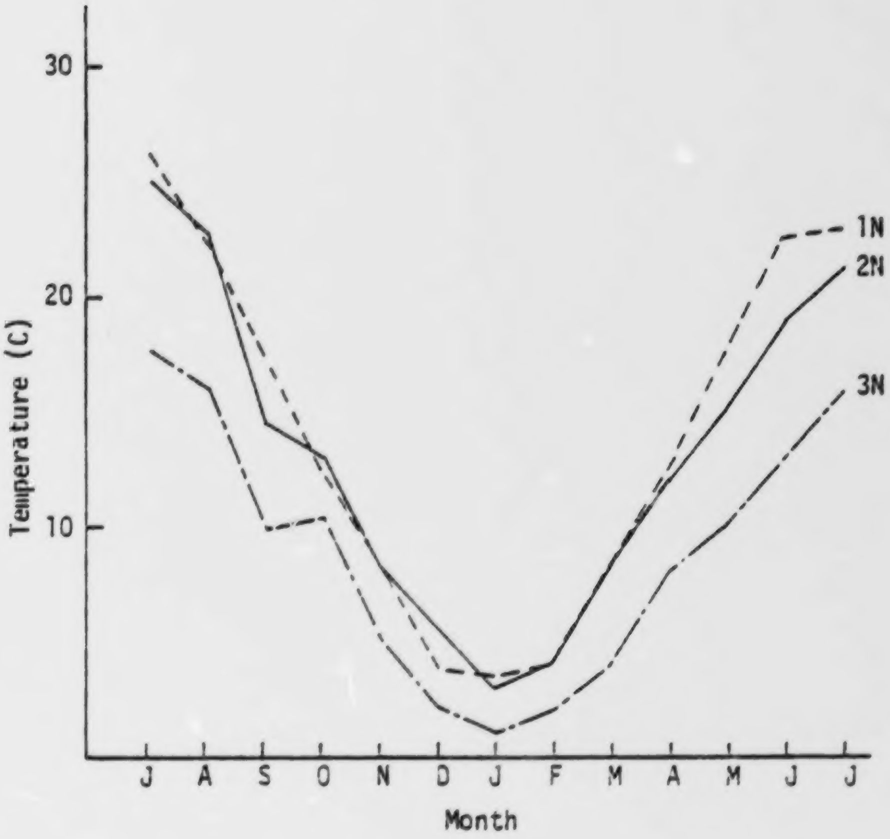


Figure 118. North Aspect Soil Temperatures at the Three Study Sites.

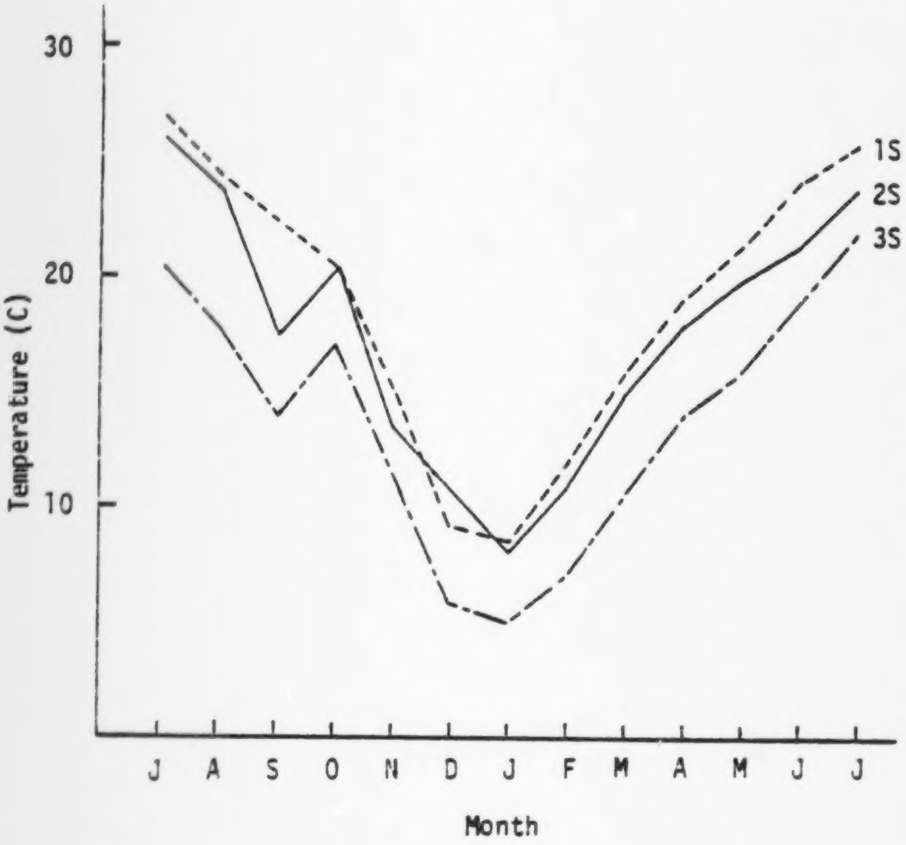


Figure 119. South Aspect Soil Temperatures at the Three Study Sites.

## TABLE 116. PARTICLE SIZE DISTRIBUTION AND COARSE FRAGMENTS

| Horizon | Depth | Sand | Silt | Clay | Coarse Fragments | Textural Class* |
|---|---|---|---|---|---|---|
| | cm | | | % | | |
| | | | Profile 1S | | | |
| A1 | 0-11 | 51.2 | 36.0 | 12.8 | | GrL |
| B1ca | 11-37 | 38.5 | 40.4 | 21.1 | 46.9 | VCobL |
| B2ca | 32-56 | 38.9 | 42.0 | 19.9 | 49.1 | VGrl |
| B3ca | 56-65 | 43.8 | 39.9 | 16.3 | | VCobL |
| | | | Profile 1N | | | |
| A11 | 0-12 | 44.3 | 37.2 | 18.5 | | L |
| A12 | 12-25 | 41.6 | 39.9 | 18.5 | | GrL |
| B1ca | 25-41 | 40.6 | 43.2 | 16.2 | 46.1 | VGrl |
| B2ca | 41-78 | 43.1 | 35.3 | 20.2 | 58.6 | VGrL |
| B3ca | 78-100+ | 48.9 | 34.8 | 16.3 | | VCobL |
| | | | Profile 2S | | | |
| A11 | 0-8 | 28.7 | 39.6 | 31.7 | | Cl |
| A12 | 8-19 | 23.8 | 46.1 | 30.1 | | GrCL |
| B2ca | 19-31 | 15.8 | 56.9 | 27.3 | 70.1 | VGrSiCL |
| B31ca | 31-46 | 16.4 | 58.7 | 24.9 | 65.6 | VGrSiL |
| B32ca | 46-62 | 23.4 | 55.8 | 20.8 | | VGrSiL |
| | | | Profile 2N | | | |
| A1 | 0-9 | 22.2 | 38.0 | 39.8 | | CL |
| B1t | 9-19 | 21.7 | 32.8 | 45.5 | | C |
| B21t | 19-34 | 21.7 | 36.9 | 41.4 | 48.4 | VGrC |
| B22t | 34-57 | 22.1 | 35.0 | 42.9 | 54.4 | VGrC |
| B3&R | 57-85 | 20.3 | 34.9 | 44.8 | | VCobC |
| | | | Profile 3S | | | |
| A11 | 0-9 | 25.3 | 43.7 | 31.0 | | CL |
| A12 | 9-21 | 29.7 | 41.3 | 29.0 | | GCL |
| B21t&R | 21-38 | 27.1 | 33.2 | 39.7 | 36.7 | GrCL |
| B22t&R | 38-62 | 28.3 | 36.6 | 35.0 | 54.2 | VGrCL |
| B3t&R | 62-72 | 24.8 | 33.7 | 41.5 | | VCobC |
| | | | Profile 3N | | | |
| A1 | 0-10 | 25.6 | 40.7 | 33.7 | | GrCL |
| B1t&R | 10-21 | 28.9 | 31.9 | 39.2 | 25.3 | GrCL |
| B21t&R | 21-38 | 27.1 | 31.8 | 41.1 | | GrC |
| B22t&R | 38-60+ | 25.2 | 31.5 | 43.3 | | GrC |

*Texture abbreviations: Gr = gravelly; VGr = very gravelly: VCob = very cobbly; L = loam; CL = clay loam; SiL = silt loam; SiCL = silty clay loam; C = clay.

Profiles 3S and 3N showed sufficient evidence of clay translocation to qualify as having argillic horizons. The clay increased significantly with depth throughout profile 3N with textures varying from clay loam and gravelly clay loam to clay. In contrast to the other sampling locations, sites 3S and 3N reflected an elevation influence more than an aspect influence on their textural characteristics. The insignificant $CaCO_3$ values for these two pedons indicated greater leaching than in the soils from the other sites.

Coarse fragment procedures were established as a check on field estimates. It is important to remember, that the gravelly modifiers used for horizons (Table 116) in which the gravel was not determined in the laboratory, were derived from field estimates only. In all pedons, coarse fragment percentages determined in the laboratory were similar to field estimates. In all sites except site 1, south aspects had the highest coarse fragment percentages, ranging from 48% at site 2N to 70% at site 2S, and from 25% to 54% at 3N and 3S, respectively. Coarse fragments appeared to increase with depth, however, the B2ca horizon in profile 2S showed a decrease in coarse fragment content with depth. Reasons for this were unclear.

As shown in Table 117, $CaCO_3$ percentages generally increased with depth. Pedons 1N, 1S, and 2S showed the highest percentages, and reflected an appreciable redistribution of $CaCO_3$. Differences also occurred between soils of opposing aspects at locations 2 and 3, where the north aspects showed the lower values. Profiles 2N and 3N were virtually noncalcareous except for small particles of limestone that were inadvertently included in the grinding process. At 2N, $CaCO_3$ increased abruptly in the lower B3 horizon due to secondary accumulation, or inheritance of small limestone particles, or both. Generally, in noncalcareous horizons, $CaCO_3$ should not exceed 1.0%. Slightly higher values indicated the presence of fine limestone particles as explained earlier. Only pedons 1N, 1S, and 2S definitely had sufficient secondary $CaCO_3$ accumulation to qualify as having calcic horizons. The B3&R horizon of pedon 2N may qualify as a calcic horizon, but additional work would be needed to determine the percentage of secondary versus primary $CaCO_3$.

## TABLE 117. SELECTED CHEMICAL PROPERTIES

| Horizon | Depth | pH | OC | $CaCO_3$ | CEC |
|---|---|---|---|---|---|
| | cm | | | | meq/100g |
| | | | Profile 1S | | |
| A1 | 0-11 | 8.2 | 0.8 | 25.4 | 13.8 |
| B1ca | 11-32 | 7.9 | 0.6 | 37.1 | 13.2 |
| B2ca | 32-56 | 7.8 | 0.6 | 46.2 | 12.4 |
| B3ca | 56-65 | 7.9 | 0.6 | 47.9 | 13.1 |
| | | | Profile 1N | | |
| A11 | 0-12 | 7.6 | 2.3 | 20.2 | 24.1 |
| A12 | 12-25 | 7.7 | 1.7 | 28.3 | 23.7 |
| B1ca | 25-41 | 7.9 | 0.6 | 44.3 | 12.7 |
| B2ca | 41-78 | 7.9 | 0.6 | 45.5 | 13.2 |
| B3ca | 78-100+ | 8.1 | 0.5 | 52.2 | 13.3 |
| | | | Profile 2S | | |
| A11 | 0-8 | 7.7 | 5.1 | 8.5 | 40.3 |
| A12 | 8-19 | 7.6 | 3.8 | 10.9 | 38.6 |
| B2ca | 19-31 | 7.8 | 3.4 | 36.8 | 33.6 |
| B31ca | 31-46 | 7.9 | 2.4 | 49.2 | 38.7 |
| B32ca | 46-62 | 8.0 | 1.9 | 55.9 | 29.3 |
| | | | Profile 2N | | |
| A1 | 0-9 | 7.6 | 5.1 | 3.7 | 53.5 |
| B1t | 9-19 | 7.4 | 3.4 | 2.9 | 46.8 |
| B21t | 19-34 | 7.4 | 2.1 | 3.2 | 38.7 |
| B22t | 34-57 | 7.4 | 1.6 | 3.3 | 38.1 |
| B3&R | 57-85 | 7.5 | 1.4 | 12.1 | 37.0 |
| | | | Profile 3S | | |
| A11 | 0-9 | 7.5 | 5.7 | 2.9 | 50.5 |
| A12 | 9-21 | 7.4 | 3.3 | 4.7 | 46.9 |
| B21t&R | 21-38 | 7.3 | 2.3 | 3.4 | 45.4 |
| B22t&R | 38-62 | 7.3 | 1.9 | 4.9 | 41.5 |
| B3t&R | 62-72 | 7.4 | 1.6 | 6.3 | 39.6 |
| | | | Profile 3N | | |
| A1 | 0-10 | 7.4 | 6.1 | 2.8 | 48.0 |
| B1t&R | 10-21 | 7.1 | 3.3 | 2.9 | 54.7 |
| B21t&R | 21-38 | 6.8 | 1.7 | 2.0 | 55.0 |
| B22t&R | 38-60+ | 7.1 | 1.6 | 2.3 | 43.9 |

Relatively high pH values reflected the calcareous nature of both profiles at site 1 and profile 2S (Table 117). In general, pH values were highest at site 1 and lowest at site 3. The lower pH values in both profiles at site 3 and profile 2N reflected increased leaching. Slight differences between pedons of opposing aspects were evident. In general, pH values for the south aspects were higher than on opposing north aspects, again because of differential leaching.

Organic carbon (Table 117) was always highest in surface (A) horizons. Variations between profiles was a function of total plant cover and soil temperature differences. Values increased markedly with increased elevation and those from north aspect profiles were appreciably higher than those from corresponding south aspects. Cooler temperatures, as well as higher precipitation and increased plant cover, resulted in the higher values.

Whole soil CEC values (Table 117) reflected the type and amount of silicate clays and organic matter content. $CaCO_3$, sand, and silt, act as diluents which mask mineralogical differences. Where $CaCO_3$ accumulations occurred, CEC values were lower than expected. CEC's from the south aspects tended to be lower than opposing north aspects, reflecting lower clay contents, lower OC values, or both. Because of relatively high organic carbon values, CEC values were higher in A horizons than in subjacent horizons with similar clay contents. Sites 2 and 3 had appreciably higher CEC values than corresponding aspects and horizons in site 1 because of higher OC values, higher clay contents, and less free $CaCO_3$.

Electrical conductivity (EC) values were given in Table 118. They were generally low in all pedons. At site 1, higher soluble salt accumulations were expected due to eolian deposition from nearby saline basins; however, EC values remained low.

Total soluble cations (Table 118) reflected EC values. Soils with low total salt concentrations showed consistently lower amounts of soluble cations. As EC values increased, $Ca^{+2}$, $Mg^{+2}$, and $Na^{+}$ increased proportionately. Potassium was generally highest in A horizons of north aspects, probably resulting from greater recycling due to the denser vegetation.

## TABLE 118. WATER SOLUBLE CATIONS, WATER SATURATION PERCENTAGE, AND ELECTRICAL CONDUCTIVITY VALUES

| | Soluble Cations | | | | Water | |
|---|---|---|---|---|---|---|
| Horizon | Ca | Mg | Na | K | Saturation | EC |
| | --------------meq/l-------------- | | | | -----%---- | mmhos/cm |
| Profile 1S | | | | | | |
| A1 | 7.0 | 3.4 | 0.9 | 0.7 | 29.7 | 0.9 |
| B1ca | 7.3 | 4.9 | 0.5 | 0.3 | 32.4 | 1.0 |
| B2ca | 6.5 | 5.2 | 1.6 | 0.2 | 29.2 | 1.4 |
| B3ca | 10.0 | 1.2 | 2.1 | 0.3 | 41.9 | 1.4 |
| Profile 1N | | | | | | |
| A11 | 12.5 | 2.4 | 0.5 | 1.0 | 42.7 | 1.2 |
| A12 | 10.5 | 2.3 | 0.6 | 0.9 | 40.5 | 1.1 |
| B1ca | 9.5 | 2.2 | 0.3 | 0.4 | 41.8 | 0.8 |
| B2ca | 9.0 | 2.4 | 0.4 | 0.3 | 38.3 | 0.8 |
| B3ca | 8.5 | 2.4 | 1.5 | 0.3 | 40.3 | 1.1 |
| Profile 2S | | | | | | |
| A11 | 9.0 | 1.2 | 0.3 | 0.2 | 44.0 | 0.9 |
| A12 | 7.7 | 1.1 | 0.6 | 0.2 | 48.9 | 1.1 |
| B2ca | 8.5 | 1.0 | 0.8 | 0.1 | 64.4 | 1.8 |
| B31ca | 14.3 | 2.3 | 2.6 | 0.2 | 61.8 | 1.6 |
| B32ca | 11.5 | 2.9 | 2.1 | 0.1 | 52.2 | 1.2 |
| Profile 2N | | | | | | |
| A1 | 15.5 | 3.4 | 2.4 | 0.8 | 57.7 | 1.5 |
| B1t | 13.5 | 2.4 | 0.3 | 0.2 | 50.7 | 1.2 |
| B21t | 12.0 | 2.1 | 0.4 | 0.2 | 55.8 | 1.0 |
| B22t | 12.0 | 2.1 | 0.7 | 0.2 | 52.4 | 1.2 |
| B3&R | 8.5 | 1.3 | 0.3 | 0.1 | 49.2 | 0.9 |
| Profile 3S | | | | | | |
| A11 | 12.3 | 2.8 | 0.4 | 0.2 | 55.4 | 1.1 |
| A12 | 15.3 | 3.4 | 1.5 | 0.2 | 54.7 | 1.2 |
| B21t&R | 12.5 | 2.6 | 0.8 | 0.1 | 55.0 | 1.1 |
| B22t&R | 11.3 | 2.2 | 0.4 | 0.1 | 55.8 | 1.0 |
| B3t&R | 10.8 | 2.2 | 0.5 | 0.1 | 48.9 | 1.0 |
| Profile 3N | | | | | | |
| A1 | 8.0 | 5.0 | 0.5 | 0.8 | 61.9 | 1.5 |
| B1t&R | 15.8 | 4.9 | 1.4 | 0.4 | 56.2 | 1.7 |
| B21t&R | 7.8 | 3.9 | 0.4 | 0.1 | 56.1 | 0.9 |
| B22t&R | 4.3 | 4.9 | 0.6 | 0.1 | 47.2 | 0.8 |

Saturation percentages (Table 118) indicated total porosities of the samples. Soils high in either silicate clays or $CaCO_3$ were more porous and required a larger volume of water for saturation. Humus and $CaCO_3$ also affected saturation values. Higher humus in surface horizons from north aspects relative to the south aspects were reflected in higher saturation values. The role of $CaCO_3$ in influencing water saturation values was rather difficult to assess. When the particles were strongly cemented into sand-size aggregates porosity was relatively low. When particles were smaller they acted more like silt and clay, thereby increasing porosity.

Water retention values (Table 119) at 1/3, 3 and 15 bar tension were expressed as gravimetric water content in percent. Values were correlated to clay and silt contents, and they also suggested an influence by $CaCO_3$. As the amount of silt increased, generally reflecting greater $CaCO_3$, available water (AW) increased. The three pedons (2N, 3N, and 3S) with the highest clay content tended to have the lowest available water due to the higher amount of water retained at 15 bars tension.

$CaCO_3$ exerted a significant influence on the two soils at site 1 and pedon 2S. Both pedons at site 1 had higher sand contents than pedon 2S, however AW was higher, due to the relatively high, mostly silt-size carbonate particles. In a comparison of 2S and 3S pedons, the effect of the higher silt content, due to the high amount of $CaCO_3$, was apparent.

It was extremely difficult to evaluate the precise effects of $CaCO_3$ on the available water-holding capacity of soils. Although laboratory-determined AW was usually high on high-carbonate soils, the sites generally appeared to be droughty as indicated by vegetation studies. Suffice it to say, that the amount and particle size of $CaCO_3$ was undoubtedly influential in soil water availability.

Extractable cations (Table 120) expressed in meq/100g indicated the presence of free $CaCO_3$. Base saturation percentages on soils containing free $CaCO_3$ almost always exceeded 100%, because $CaCO_3$ was dissolved by the $NH_4$(Ac) extractant. This applied to sites 1N, 1S, and 2S, as well as the lower part of profiles 2N and 3S. Lower percent

## TABLE 119. WATER RETENTION VALUES AND AVAILABLE WATER

| | | | Tension (bars) | | Available |
|---|---|---|---|---|---|
| Horizon | Depth | 1/3 | 3 | 15 | Water |
| | cm | | % | | |
| | | | Profile 1S | | |
| A1 | 0-11 | 23.4 | 11.6 | 9.6 | 13.8 |
| B1ca | 11-32 | 24.6 | 12.3 | 10.3 | 14.3 |
| B2ca | 32-56 | 27.9 | 12.2 | 14.0 | 13.9 |
| B3ca | 56-65 | 24.8 | 15.4 | 12.4 | 12.4 |
| | | | Profile 1N | | |
| A11 | 0-12 | 22.7 | 15.3 | 9.2 | 13.5 |
| A12 | 12-25 | 23.8 | 15.8 | 10.4 | 13.4 |
| B1ca | 25-41 | 27.3 | 18.0 | 12.8 | 14.5 |
| B2ca | 71-78 | 27.9 | 15.8 | 12.7 | 15.2 |
| B3ca | 78-100+ | 25.4 | 18.1 | 10.6 | 14.8 |
| | | | Profile 2S | | |
| A11 | 0-8 | 25.2 | 24.7 | 12.5 | 12.7 |
| A12 | 8-19 | 25.6 | 23.5 | 12.0 | 13.6 |
| B2ca | 19-31 | 26.2 | 22.5 | 13.0 | 13.2 |
| B31ca | 31-46 | 27.0 | 22.2 | 13.6 | 13.4 |
| B32ca | 46-62 | 27.6 | 21.7 | 12.4 | 15.2 |
| | | | Profile 2N | | |
| A1 | 0-9 | 27.7 | 19.8 | 15.8 | 11.9 |
| B1t | 9-19 | 29.1 | 22.6 | 16.2 | 12.9 |
| B21t | 19-34 | 28.7 | 30.8 | 16.3 | 12.4 |
| B22t | 34-57 | 29.3 | 29.1 | 17.1 | 12.2 |
| B3&R | 57-85 | 30.8 | 25.2 | 18.5 | 12.3 |
| | | | Profile 3S | | |
| A11 | 0-9 | 24.5 | 25.8 | 12.6 | 11.9 |
| A12 | 9-21 | 24.1 | 23.9 | 12.2 | 11.9 |
| B21t&R | 21-38 | 26.2 | 24.1 | 14.2 | 12.0 |
| B22t&R | 38-62 | 24.8 | 23.1 | 13.7 | 11.1 |
| B3t&R | 62-72 | 26.6 | 20.7 | 15.3 | 11.3 |
| | | | Profile 3N | | |
| A1 | 0-10 | 24.0 | 33.7 | 13.4 | 10.6 |
| B1t&R | 10-21 | 26.1 | 25.0 | 14.2 | 11.9 |
| B21t&R | 21-38 | 27.2 | 25.4 | 15.4 | 11.8 |
| B22t&R | 38-60+ | 26.8 | 21.3 | 17.7 | 9.1 |

## TABLE 120. AMMONIUM ACETATE EXTRACTABLE CATIONS, AND PERCENTAGE BASE SATURATION

| | Cation | | | | Base |
|---|---|---|---|---|---|
| Horizon | Ca | Mg | Na | K | Saturation* |
| | ---------------meq/100gm----------- | | | | % |
| | | | Profile 1S | | |
| A1 | 69.9 | 5.8 | 1.1 | 0.8 | -- |
| B1ca | 84.4 | 6.1 | 1.1 | 0.5 | -- |
| B2ca | 77.2 | 7.6 | 0.9 | 0.4 | -- |
| B3ca | 63.9 | 7.4 | 1.1 | 0.3 | -- |
| | | | Profile 1N | | |
| A11 | 87.2 | 2.6 | 0.9 | 1.2 | -- |
| A12 | 76.7 | 2.4 | 0.9 | 0.9 | -- |
| B1ca | 80.1 | 2.5 | 0.8 | 0.4 | -- |
| B2ca | 68.5 | 2.4 | 0.8 | 0.3 | -- |
| B3ca | 78.9 | 2.8 | 0.9 | 0.3 | -- |
| | | | Profile 2S | | |
| A11 | 86.4 | 2.1 | 1.0 | 1.0 | -- |
| A12 | 95.2 | 2.1 | 1.2 | 0.8 | -- |
| B2ca | 109.8 | 1.8 | 1.4 | 0.5 | -- |
| B31ca | 94.5 | 2.9 | 1.3 | 0.5 | -- |
| B32ca | 100.7 | 3.4 | 1.3 | 0.3 | -- |
| | | | Profile 2N | | |
| A1 | 44.5 | 4.5 | 1.0 | 2.1 | 97.4 |
| B1t | 31.9 | 2.9 | 0.8 | 1.1 | 78.4 |
| B21t | 41.2 | 3.1 | 0.9 | 1.1 | -- |
| B22t | 39.9 | 2.9 | 0.8 | 0.7 | -- |
| B3&R | 39.9 | 2.2 | 1.0 | 0.7 | -- |
| | | | Profile 3S | | |
| A11 | 36.7 | 5.0 | 1.0 | 1.2 | 86.9 |
| A12 | 55.6 | 4.9 | 0.8 | 0.7 | -- |
| B21t&R | 36.4 | 4.1 | 0.5 | 0.7 | 91.8 |
| B22t&R | 42.3 | 3.8 | 0.5 | 0.5 | -- |
| B3t&R | 60.1 | 3.6 | 0.6 | 0.4 | -- |
| | | | Profile 3N | | |
| A1 | 35.4 | 9.0 | 0.9 | 2.1 | -- |
| B1t&R | 20.3 | 8.9 | 0.7 | 1.2 | 56.8 |
| B21t&R | 24.8 | 7.7 | 0.5 | 0.8 | 61.4 |
| B22t&R | 19.1 | 7.2 | 0.5 | 0.5 | 62.2 |

*Where data are not listed, percent base saturation exceeds 100%.

base saturation values suggested a greater amount of leaching, e.g., pedon 3N. At site 3N, the high base saturation of the A1 horizon may have been caused by the recycling of cations especially by the dominant coniferous vegetation.

X-ray diffraction analysis was an exceedingly useful tool in mineral identification and often was the only direct way of confirming the presence of a mineral in soil clays. However, it was still only semiquantitative even when careful techniques, which had been standardized in preliminary work on the soils under investigation or on similar soils, were used. Clear-cut depth or functional soil trends could be confirmed using less precise techniques, but when trends were less evident, speculation as to possibilities may have been the only statements that could be made. Although a high percentage of the clay mineralogy performed in the United States, both by soil scientists and geologists, was done on the whole clay fraction (< 2 μm), separation into at least two subfractions, coarse clay (2-0.2 μm) and fine clay (< 0.2 μm) and subsequent x-raying of them is highly desirable. Separation into subfractions was not done in the study reported herein because: (1) gross functional trends and mineralogical data as they affected physical and chemical soil properties were the main concerns, and (2) the tedious, time-consuming nature of the separation process.

In examining diffractograms of clay from individual pedons (Figures 120-122), several precautions were in order: (1) despite using approximately the same amount of suspension for each sample the concentration of the suspension varied greatly, resulting in differences in amounts of clay oriented on the slide. This made comparisons between treatments, i.e., Ca-glycerol solvated and K-saturated, heated samples, difficult. Moreover, problems arose when comparing horizons within the same profile, as well as between aspects and site elevations. (2) Inadvertent enrichment of either coarse or fine clay during the pipetting of the suspensions onto the glass slide was indicated in some diffractograms, e.g., the B22t horizon of 3N (Figure 122). The K-saturated, heated sample almost surely had more coarse clay as indicated by the strong kaolinite (7.1Å) peak as contrasted to the Ca-glycerol solvated peak. Moreover, the indication of quartz in relatively large amounts in some diffractograms, e.g., 1N A11 and 2N

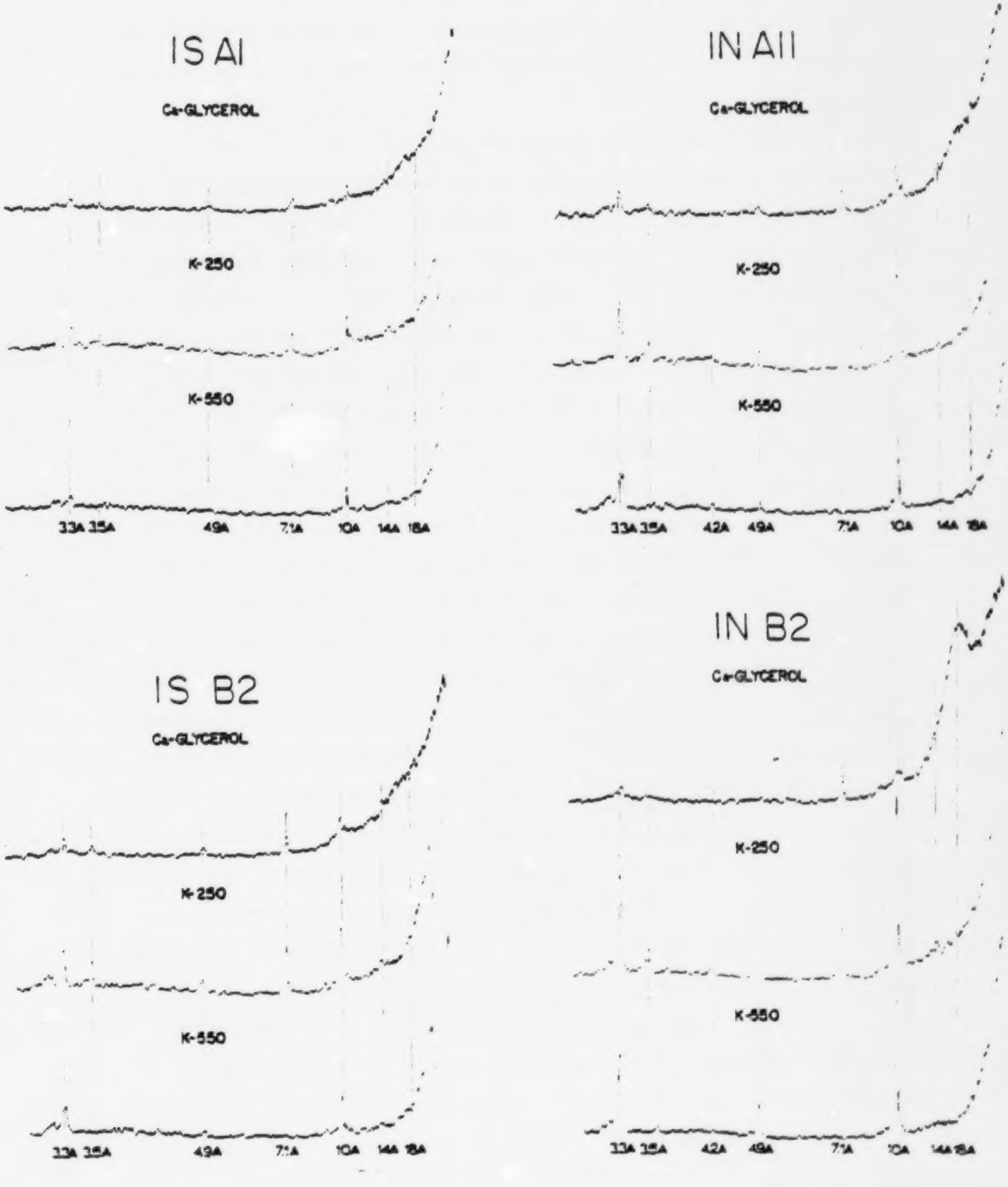


Figure 120. Diffractograms of Selected Horizons on South and North Aspects Site 1.

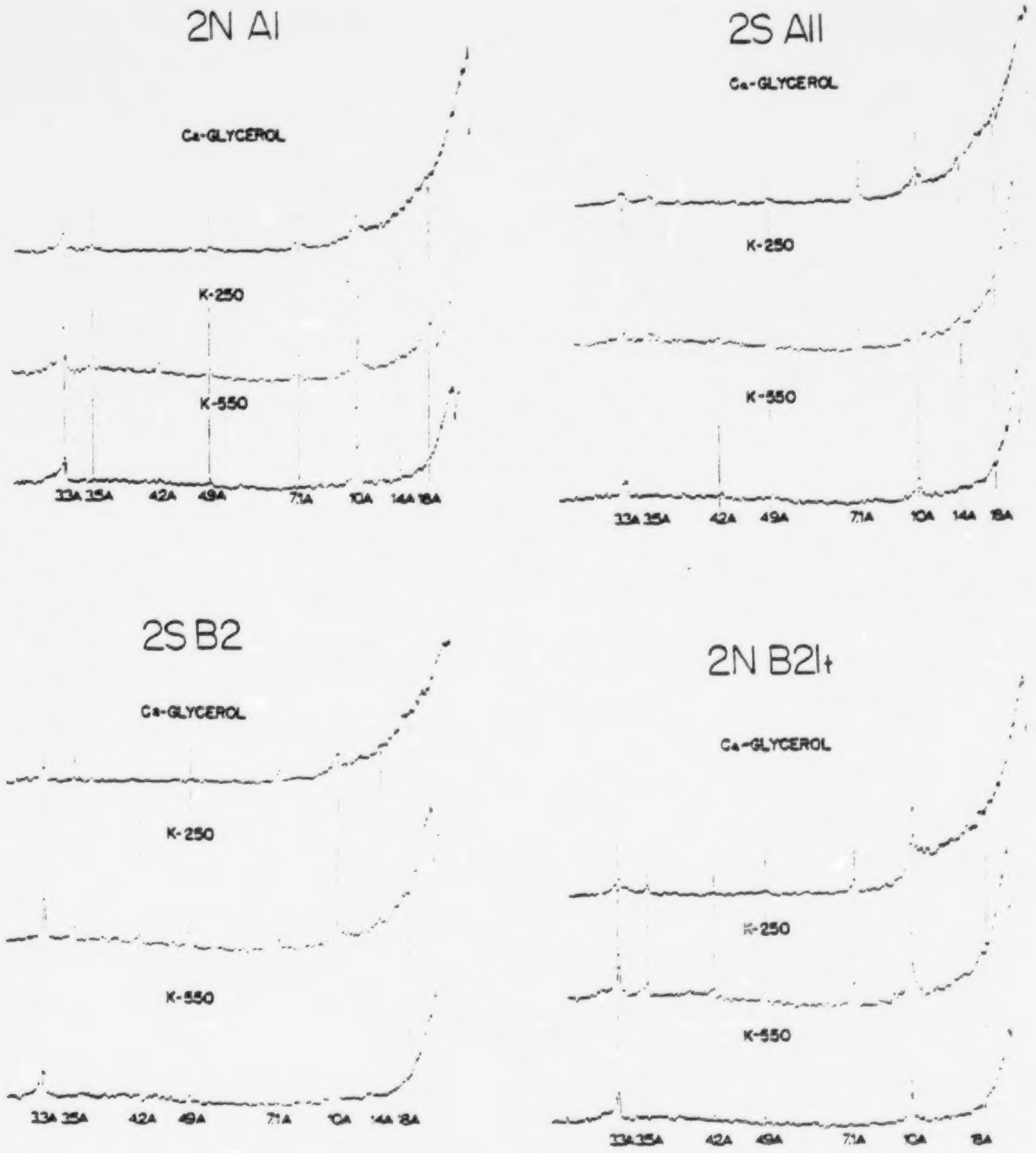


Figure 121. Diffractograms of Selected Horizons on South and North Aspects Site 2.

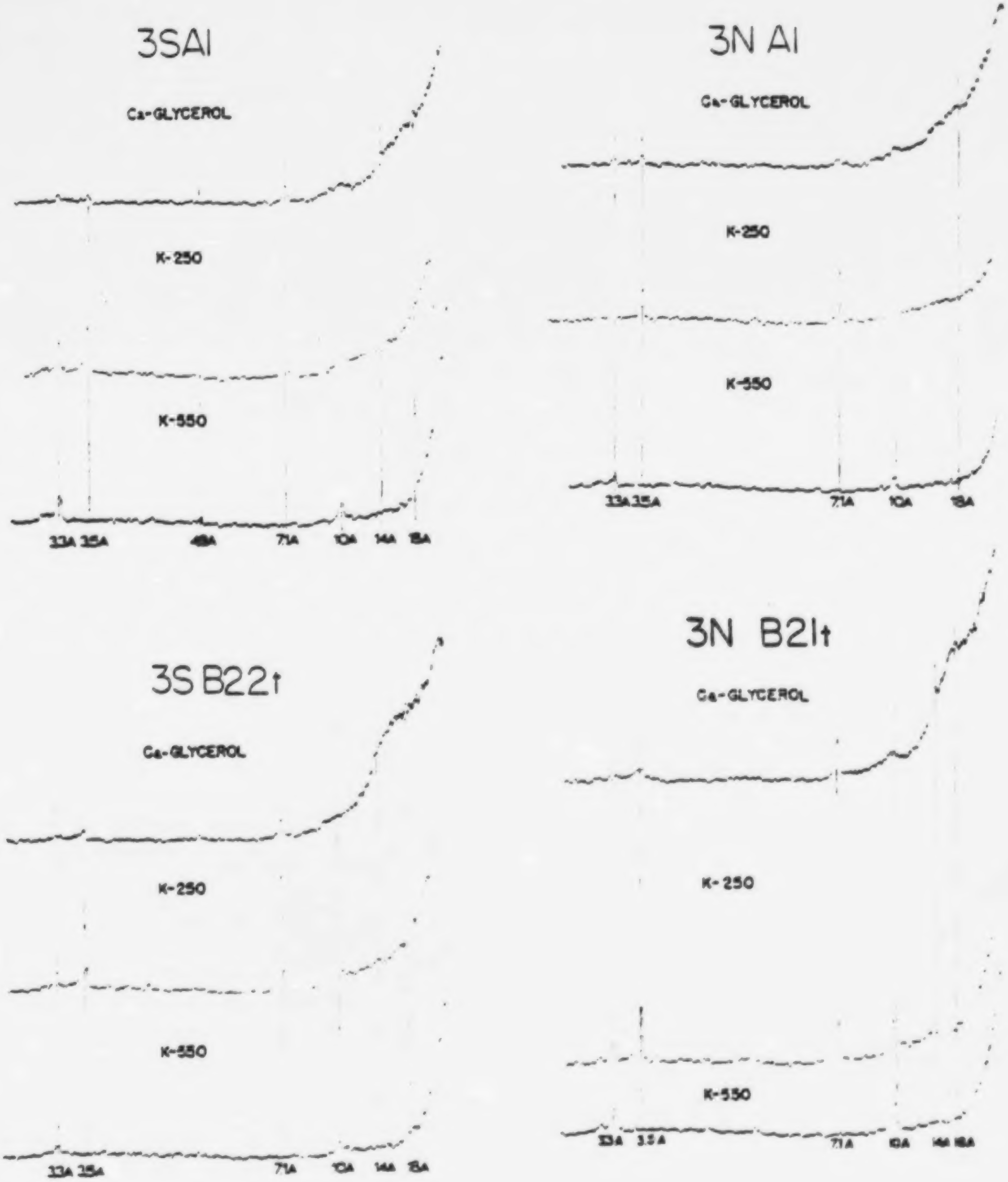


Figure 122. Diffractograms of Selected Horizons on South and North Aspects Site 3.

B21t and its absence in other diffractograms, e.g., all those from site 3, would indicate preferential separation during the slide presentation. (Fine clay does not contain quartz.) (3) The presence of excess glycerol is suggested in some patterns, e.g., 1S A1 (Figure 120). When glycerol is present, orientation of the phyllosilicate particles is adversely affected, resulting in weaker peaks generally. One further precaution was that the K-saturated and heated samples from sites 1S, 1N, 2S, and 3S, were initially started at 1000 cps in order to prevent the recording needle from extending beyond the chart limits. After approximately 1°2θ they were switched to 500 cps to accommodate the peak reflections in a uniform manner. Therefore none of the "peaks" at approximately 3°2θ on these diffractograms are actually peak reflections of a particular mineral, but rather an indication of where the switch occurred.

Diagnostic reflections of the most frequently encountered clay minerals were listed in Table 121. Diffractograms of clays from the different sites indicate relatively large amounts of illite and kaolinite. Illite was identified by the characteristic 9.9 and 3.3 Å reflections which persisted throughout all three treatments. A second order 4.9 - 5.0 Å peak was detected on some diffractograms. The 7.1 and 3.5 Å peaks are indicative of kaolinite in the Ca-glycerol and K-250 treatments. Their absence in the K-550 treatment is further confirmation of kaolinite in the samples since the crystalline structure of kaolinite is destroyed upon heating to 550C. Smectite occurs either as discrete particles or as a component interstratified with illite. Discrete smectite was identified by an 18 Å peak with a Ca-glycerol treatment, e.g., the 1N B2 sample. Smectite-illite interstratification is suggested in most of the samples by the diffuse reflection in the 14-18 Å region and its distinct reduction upon K-saturation and heating to 250C. Chlorite, occurring only in small quantities, was identified by the weak 14 Å peak. Both chlorite and kaolinite are believed to have been inherited from the parent rock, since chlorite is very rare, and kaolinite forms only a minor component in West Texas and southeastern New Mexico soils heretofore analyzed.

X-ray diffraction analyses show that the clay mineralogy in all pedons was mixed. Neither elevation nor aspect functional trends could

TABLE 121. X-RAY DIFFRACTION SPACINGS OF SELECTED MINERALS

| Minerals | Degrees (2θ) | d Spacing (Angstroms) | hkl |
|---|---|---|---|
| Illite | 8.8- 9.0 | 10.0- 9.9 | 002 |
| | 17.6-17.8 | 5.0- 4.9 | 004 |
| | 26.7-26.8 | 3.3 | 006 |
| Kaolinite | 12.4-12.5 | 7.1 | 001 |
| | 24.8-25.0 | 3.55 | 002 |
| Smectite | 4.9- 5.0 | 18.0-17.7 | 001 |
| | 9.7- 9.9 | 9.1- 8.9 | 002 |
| Quartz | 20.9 | 4.26 | 100 |
| | 26.6 | 3.33 | |
| Chlorite | 6.3 | 14 | 001 |

be established on the basis of present data. Moreover, changes in mineralogy with profile depth were not obvious although an increase in smectite in some pedons was indicated, e.g., pedon 1N and 3N. Larger amounts of smectite were probably present than indicated by the diffractograms when the relatively high CEC's listed in Table 117 were considered.

Analysis of clay extracted from the parent limestone needed to be performed to confirm the inheritance of chlorite and most of the kaolinite. Results reported herein should be considered of a preliminary nature and more detailed work is needed to determine more precisely the mineralogical effects on soil physical and chemical properties. Additional work is also needed to determine the importance of the eolian contribution to the parent sediments.

Soils at each study site were classified to the family level (Table 122). The application of the gravelly modifier was determined from laboratory studies and extrapolation of field estimates on horizons not analyzed in the laboratory. All suborders were described as "lithic" since they all overlay limestone bedrock. Depth to the lithic subgroups as defined by Soil Taxonomy (Soil Survey Staff, 1975) is within 50 cm of the soil surface. However, in pedons 1N, 1S, 2N, and 2S, depth to the lithic contact exceeded specified depth. This could be explained by the methods of description and sampling employed. In order to study the depth of clay movement within each profile, pits were dug so that the material in crevices of the bedrock could be described and sampled.

Profile 1S was classified as a Lithic Calciorthid. It had a calcic horizon with its upper boundary 20 cm from the soil surface, and was calcareous throughout. It occurred on a mountain upland site with a slope of 30 percent. Site 1S had a thermic temperature regime with a MAST of 18.3C.

Profile 1N was classified as a Lithic Calciustoll. It had a mollic epipedon with a calcic horizon within 25 cm of the soil surface. The difference in classification between pedons on opposite slopes was probably due to lower temperatures of the north aspect. However, at the family level, both were classified as loamy-skeletal and as having carbonatic mineralogies. Site 1N had a mesic temperature regime with a MAST of 13.3C; however, the general area of site 1 was definitely thermic.

TABLE 122. CLASSIFICATION OF SOILS

| Pedon | Subgroup | | Series |
|---|---|---|---|
| 1S | Lithic Calciorthid | loamy-skeletal, carbonatic, thermic | Lozier |
| 1N | Lithic Calciustoll | loamy-skeletal, carbonatic, thermic | Ector |
| 2S | Lithic Calciustoll | loamy-skeletal, carbonatic, mesic | Deama* |
| 2N | Lithic Argiustoll | clayey-skeletal, mixed, mesic | Flume** |
| 3S | Lithic Argiustoll | clayey-skeletal, mixed, mesic | Flume** |
| 3N | Lithic Argiustoll | clayey-skeletal, mixed mesic | Flume** |

*Taxajunct to the series. It is more silty than is the Deama series as defined.

**Tentative series.

Profile 2S was classified as a Lithic Calciustoll. The profile was calcareous throughout with a calcic horizon within 20 cm of the surface. It occurred in the mountain uplands and had a slope of 28%. This profile was also classed as loamy-skeletal with a carbonatic mineralogy.

Profile 2N classified as Lithic Argiustoll, was leached to approximately 50 cm and exhibited evidence of clay translocation, reflecting a more effective moisture regime. Profiles 2S and 2N occurred in areas with predominately mesic temperatures, however 2S was thermic with a MAST of 17.1C.

Classification of profiles at site 3 are fine-skeletal, mixed, mesic, Lithic Argiustolls. Precipitation was sufficiently high because of the increased elevation to offset the influence of aspect, i.e., both soils were leached of $CaCO_3$ in the solum, permitting an argillic horizon to develop. Both pedons occurred in mountain upland positions with pedon 3S having a slope of 26% and pedon 3N having a slope of 25%.

## CONCLUSIONS

On the basis of the data obtained it may be concluded that:

1. Soils differ appreciably as a function of both elevation and aspect in Guadalupe Mountains National Park. As elevation increases, more leaching of $CaCO_3$ is evident, the soils are more clayey and exhibit evidence of clay translocation, have more organic carbon, and percentage base saturation decreases. Soils on north aspects, compared to those on south aspects, exhibit similar trends.

2. Soil temperatures vary significantly as a function of both aspect and elevation. Values obtained indicate that only thermic and mesic temperature regimes occur in the Park. Mesic temperatures are predicted to occur on north aspects above elevations of 1525 m (5000 ft.), and on south aspects above elevations of 1645 m (5400 ft.). Mesic temperatures would be expected at elevations between 1525 and 1645 m on other aspects.

# CHAPTER VIII WATER QUALITY

## INTRODUCTION

With approximately 100,000 people visiting a portion of Guadalupe Mountains National Park each year, whether the visitor stops by the roadside or engages in one of the various activities afforded by the park, the impact of each person is important in the protection of this unique ecosystem.

Many species of plant and animal life achieve their northern, southern, eastern and westernmost reaches within the confines of the park. Human impacts which affect the fragile ecological balance of these species are detrimental to the achievement of the management objectives currently in effect (Fuller, 1976).

> Any development of any degree, including trail reconstruction, will alter the ecosystems to some extent. In addition, any visitor use of the park, including hiker use, will also alter the ecosystem. Springs and seeps, if used for human water needs, would jeopardize water sources vital to wildlife and vegetation. Compaction of soil and erosion caused by foot and horse traffic is expected to contribute the largest element of environmental damage, though other factors associated with increased visitor use, such as littering, and some limited vandalism, will also pose management problems. (National Park Service, 1975).

Water is a rare and valuable resource in the park. The springs and the one perennial stream in the park are in a fragile balance with the surrounding desert environment. Recreational usage may stress this balance through addition of nutrients to the water or damage to the riparian communities. At the present time the water resources are apparently receiving minimal human usage. Data from the water quality studies may be evaluated on the basis of minimal present day use and previous use of the water resources in the park; the results of the analyses should be helpful in formulating future park management practices.

## HISTORY OF WATER USE IN THE PARK

Evidence has been found in the area that dates man's occupation to 12,000 years before the present (Davy, undated; Sprangle, 1960). About 8,000 years ago the current arid and semi-arid climatic regimes evolved which reduced the water supply in the area, and thus, restricted man's occupation of the area (Van Denender and Spaulding, 1979).

In the mid-1500's, the Spanish explorers may have used some of the springs in the area. Their use was small compared to the Mescalero Apache who frequented springs in the area extensively. Evidence of agave-roasting pits near some springs can still be seen today (Kurtz and Goran, 1978). Environmental effects of this early use on the springs and stream were apparently minimal and have generally been erased by the passage of time.

The lust for gold brought numerous adventurers into contact with the Guadalupe Mountains in 1849, and increased significantly spring and stream usage by those using the California Trail which passed the base of the mountains near Pine and Guadalupe Springs (Kurtz and Goran, 1978).

In 1856, a transcontinental mail route was established which later became the Butterfield Stage Route. Pine Spring was to supply water to the Pinery Stage stop for only 11 months before the stage stop was moved further south. Although Pine Spring ceased providing the water need of the stage enterprise, it continued to supply water for many other uses until an earthquake in 1931, stopped its flow.

After the defeat of the Mescalero Apache in the 1860's ranchers started moving into the area. Frijole Spring was the site of the first permanent house in the area. Built in 1876, the house is presently used as a ranger residence. The spring house, built in the 1870's, still covers the spring and serves today's domestic water supply needs.

Upper Pine Spring, or Bear Spring as it is sometimes called, was used for a unique and innovative livestock water distribution system previously discussed in Chapter II.

Bone Spring on the arid west side of the park was possibly a Comanche campsite (Brunne, 1975). In the early 1900's, the Williams Ranch was built at the mouth of Bone Canyon. Water for the house was piped from nearby Bone Spring. Today the Williams Ranch is a historical site in the park, but is not yet developed for park visitor use and remains inaccessible to most park visitors.

Smith, Manzanita, Choza and Upper Dog Canyon Springs have had minimal human use. Livestock and wildlife have been the most frequent users of these springs.

Guadalupe Spring was developed as a major source of water for livestock as well as for the human needs of park service personnel living below Guadalupe Pass. In 1979, the spring flow was diverted back to a natural water supply for wildlife, following the development of a deep well at the park service housing site.

There are other smaller springs in the park, but the ones mentioned are the major springs which currently and potentially will receive the heaviest human impact, (Figure 123).

McKittrick Canyon, which contains the only perennial stream in the park, was certainly used by early man. In the 1920's and 1930's, two houses were built in McKittrick Canyon. One, the Hunter Line Cabin, was built in South McKittrick Canyon while the other, the Pratt Lodge, was built at the confluence of North and South McKittrick Canyons. Sewage effluent from both houses was disposed of in cesspools on alluvial terraces near the channel. The cesspool at the Hunter Line Cabin was closed in 1970. However, the Pratt Lodge cesspool continues in use for the restroom facilities serving hikers and the lodge, which is used as a ranger residence.

Until 1970, vehicular traffic along the primitive McKittrick Canyon road, which intersected the stream bed at several junctions, could travel as far as the Hunter Line Cabin. After 1970, vehicular traffic was no longer permitted into the canyon. Today McKittrick Canyon can be seen only by walking and is operated as a day-use only area.

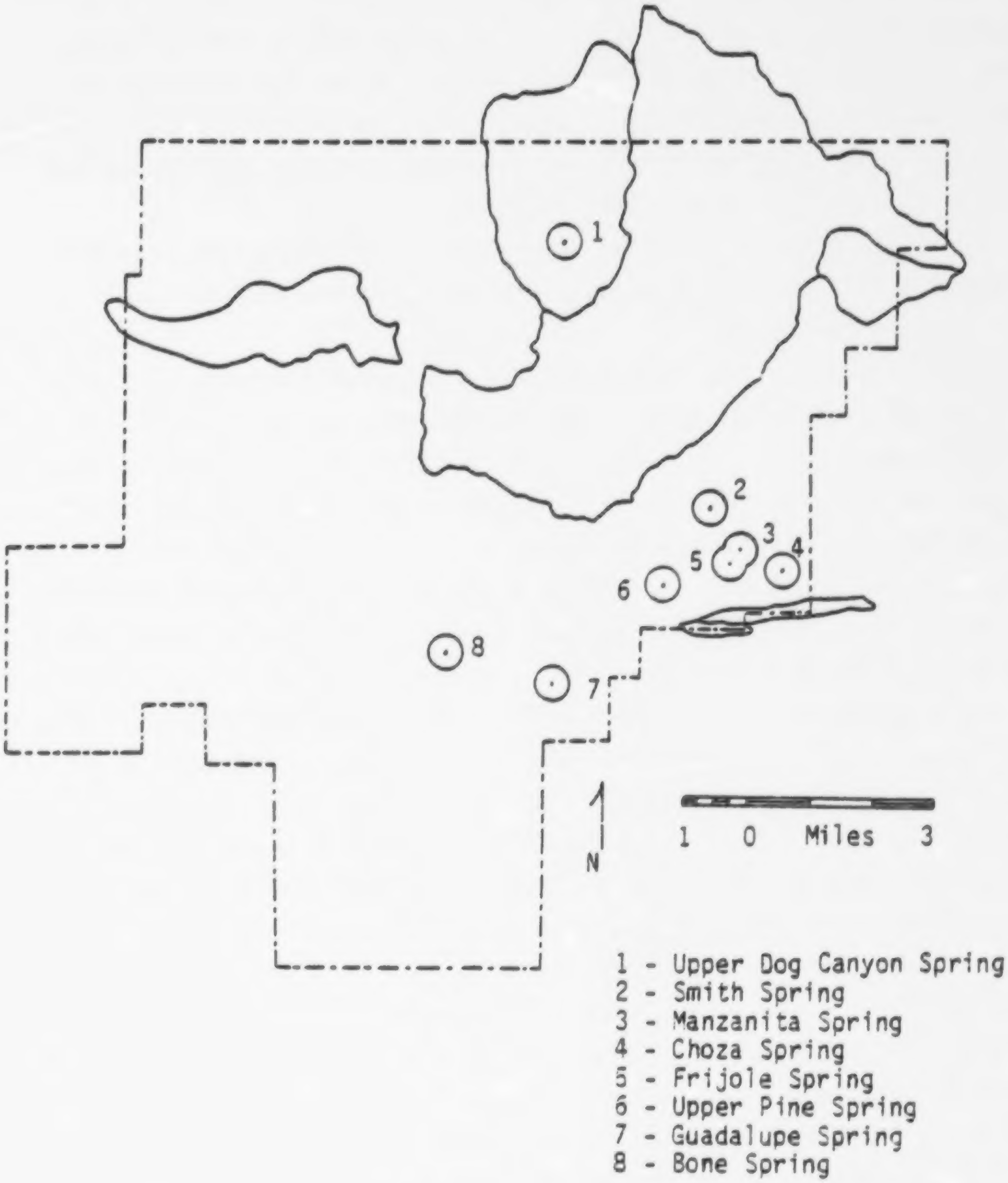


Figure 123. Sampled Spring Locations.

Current regulations, such as requiring park visitors to walk only along designated trails and not permitting them to camp around the springs or in McKittrick Canyon, are helping to insure minimal disturbance of the water sources in the park. The effects of ranching in the recent past may have had a greater impact on the chemical water quality than the park's present-day managed recreational use.

## PREVIOUS WORK

In the United States, as both population and leisure time increase, it seems likely that wilderness areas will be subjected to greater and greater use. If there is continued increasing use of wilderness areas, a threshold level eventually will be reached at which recreational use is significantly polluting the watershed (Auckerman and Springer, 1976).

Numerous factors affect the quality of water, including the interaction of runoff, soil material, and land use. Water quality characteristics may also vary according to the source of water, whether it be a well, spring, or surface water.

Several parameters must be analyzed to determine changes in water quality brought about by changes in land use. In managing a watershed and the quality of its water sources, it is essential to establish at first some idea of what the natural quality of the water is (Fish, 1972). Groundwater is the principle water source for the springs and stream in the Guadalupe Mountains National Park. Because of this, the relationship between the geology and groundwater chemistry is an important factor to consider in examining the natural water quality of the springs and stream. King (1948) studied and reported on the geology of the Guadalupe Mountains. Studies by Fish (1972) and Hem (1970), on the relationship of groundwater chemistry to geology, help in accessing the natural water quality in the park.

The majority of rock in the Guadalupe Mountains National Park is of sedimentary origin. Limestone, sandstone, alluvial material, carbonate and evaporative sediments constitute the principle rock material of the area. Table **123** shows some of the possible chemicals that may be present in surface waters of the park coming from groundwater that has been in contact with sedimentary deposits. Phosphorous, for example, is probably derived partially from the $Ca_3(PO_4)_2$ which is

TABLE 123. WATER QUALITY DATA ON WATER FROM WELLS IN GENERAL THAT WERE DRILLED IN SEDIMENTARY ROCK

|  | 1* | 2* | 3* | 4** | 5** | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| pH | - | 7.0 | 9.2 | 7.2 | 7.5 | 9.2 | 7.0 |
| Sulfate | 1,570. | 315. | 64. | 2.5 | 46.5 | 1,570. | 2.5 |
| Chloride | 24. | 42. | 16. | 8.5 | 80.0 | 80. | 8.5 |
| Total Hardness | - | - | - | 303. | 212. | 303. | 212. |
| Calcium Hardness | 1,590. | 350. | 2. | 298. | 106. | 1,590. | 2. |
| Total Alkalinity | - | - | - | 275. | 230. | 275. | 230. |
| Specific Conductance | 2,510. | 1,040. | 630. | - | - | 2,510. | 630. |

Source: *White, D.E., Hem, J.D., and Waring, G.A., chemical composition of subsurface waters, U.S. Geol. Surv. Profess. Paper, 440-F, 1963, p. F8. **Rodda, J.C., Downing, and Law, F.M., Systematic hydrology, Newnes-Butterworths, London, 1976, p. 290.

Note: General type of sedimentary rock the well is drilled in: #1 Gypsum, #2 Limestone, #3 Sandstone, #4 and #5 in Limestone. Sulfate and chloride are in mg/l and total hardness, calcium hardness and total alkalinity are in mg/l as $CaCO_3$. Specific conductance is in micromhos/cm at 25C.

present in the sedimentary deposits. King (1948), in his analyses of the material in various rock samples throughout the area, noted $Ca_3(PO_4)_2$ constituting between 0.03% and 1% of the material sampled.

The chemistry of the water resources in the Guadalupe Mountains National Park tend to strongly reflect sedimentary geology. Lind (1979), in writing about McKitrick Canyon Stream, states: "The water chemistry reflects the limestone substrate of the region . . . a well-buffered calcium carbonate-magnesium carbonate system . . . bicarbonate being the principal anion."

Another contributor to the chemical nature of the springs and stream in the Guadalupe Mountains National Park is the allochtonous input, such as leaf litter. In many of the springs and in the stream, fall leaf litter is present in large quantities. Allochtonous inputs, especially fall leaf litter, may be a principle source of nitrogen and to a lesser extent phosphorous. In a study on the Hubbard Brook Experimental Forest in New Hampshire the relative abundance of nitrogen, calcium and potassium in the litter fall was 80.6% of the total analyses for nitrogen, calcium, potassium, manganese, magnesium, sulfur, phosphorous, zinc, iron, sodium and copper. Autumn litter fall (plant debris) accounts for approximately 49.7% of the total yearly litter fall in the Hubbard Brook Experimental Forest. The autumn litter fall also contained 56.0% of the total yearly amount of the 11 elements studied (Gosz, et al., 1972).

Floods may also affect the chemical nature of the water resources in the park. Both the 1969 and the 1978 floods, probably affected the chemical constituents in the McKittrick Canyon Stream. The intervening years between these floods provided an excellent opportunity for organic detritus to accumulate on the watershed. The 1978 flood, which occurred near the end of September and flushed most of the detritus from the springs and stream, may have disturbed the dynamic equilibrium of the ecosystem similarly to the 1969 flood. Lind (1971) found that the diversity of the bottom fauna populations in 1971 was slightly lower than that of a 1969 study before the flood. The Margalef Diversity Index was 3.5 in 1969, and 3.0 in 1971.

A majority of the studies of recreational land use and its effects on water quality point to minimum impacts. Carswell, et al.

(1969) reviewed five studies indicating that recreational use has little effect on water quality. These studies are California Department of Public Health (1961); Roseberry (1964); Karalekas and Lynch (1965); Minkos (1965) and the Department of Health, Education and Welfare (1966). The reviewers mention that these studies were criticized on shortcomings, such as: including no controls, i.e., failing to compare the water quality parameters studied at the recreational site with water quality parameters from a similar site without the recreational activities; and using total coliforms as the only index of a water's sanitary quality. Dukta (1973) states that total coliforms are inadequate indices of sanitary water quality.

Other studies, using controls, support the view that recreational use causes little adverse impact on water quality. Lee, et al. (1970) reported on a study dealing with closed, minimal use and open watersheds located in Washington. Their report concludes that no measurable influence could be determined from microbiological indicator populations or chemical water quality because of increased human use of the watersheds.

Bissonette (1971), Stuart, et al. (1971) and Walter and Bottman (1967) in studying two similar watersheds, one open and one closed to the public in Montana, arrived at an unexpected observation. Surprisingly, fecal coliform concentrations in the closed watershed were generally higher than in the open watershed. The increased concentration in the water of the closed watershed was probably due to wildlife populations in the area. After the closed watershed was opened for limited use in 1970, a significant drop in bacterial levels was recorded.

Since it is basically open only to hikers, backpackers and wildlife, the Guadalupe Mountains National Park may be considered a minimal use area compared to many other recreational areas. Skinner, et al. (1974), concluded that the hikers had little or no adverse effect on the water quality.

Other studies conclude that recreational use of water may cause an increase in bacterial counts. Wagenet and Lawrence (1974) studied Lake Thunderbird in Oklahoma and found a high correlation between recreational use and bacterial counts. Dietrich and Mullamoottil (1974) arrived at a similar conclusion for a reservoir in Canada. Johnson (1975), in a study on recreational use and water quality in the Wasatch Range in Utah, ended his report with the conclusion that a relationship between total visitor use and an increase in total coliforms might have existed.

Auckerman and Springer (1976), in studying the effects of recreation on water quality in Colorado's Cache la Poudre River watershed, found that more cases of bacterial pollution are associated with recreational use by motorized campers as compared with backpackers. Perrine and Mah (1979) studied the Inyo National Forest in the Sierra Nevada and concluded that the water quality in areas allowing only backpackers is generally good.

Several previous studies of water resources in and adjacent to the park exist and provided an initial reference for the present work. One of the earliest references to water quality in the area was by Marcy (1859):

> There were several [mineral] springs at this place, the waters of which unite and form the Delaware Creek. . . . Is it not within the scope of probabilities that those springs may be found to possess valuable medicinal properties, and that this place may yet (and at no very distant period) become a place of fashionable resort for the "upper ten-thousand of New Mexico? The climate here is delightful, the atmosphere perfectly elastic and pure, and the temperature uniform and delicious. . . ."

Other early accounts of the water resources of the Guadalupe Mountains were made by Richardson (1904) and King (1948). Groundwater investigations of the Salt Basin located west of the park have been made by Scalapino (1950) and Davis and Leggat (1965). Groundwater in the Dell City area has been investigated by the Texas Water Commission (1964) and the State of New Mexico has studied the groundwater north of Dell City in the Crow Flats area of New Mexico (Bjorkland, 1957).

To date one of the most extensive studies of the water resources of the Guadalupe Mountains National Park was accomplished by Leggat (1969). This appraisal of the water resources included an inventory of all sources of water in the park, including wells, springs, and streams. The quantity and quality of each of the sources was determined. (Note--This report is a file document; the author and agency have requested that the data not be published.)

Lind (1971, 1979) studied the limnology of the McKittrick Canyon stream and several of the major springs. His chemical water quality data on the stream and some of the springs are presented in Tables 124-125. Unusually high levels of nitrate-nitrogen were found at three springs. Levels of 10 mg/l for Manzanita, 50 mg/l for Choza and 50 mg/l for Upper Pine were recorded. At the same time a level of 0.46 mg/l was recorded for Smith Spring. These results were derived from a single sample from the springs between the 8th and 10th of April 1971. The reason for these high levels was not stated in the report. High diversity indices were found in McKittrick Canyon Stream indicating a mature and stable stream ecosystem. Concern was expressed in the report that park visitor overuse or misuse may damage the McKittrick Stream ecosystem.

Dick (1975) of the Texas Water Quality Board conducted a study concentrating on the chemical and bacteriological quality of Guadalupe, Upper Pine, Smith, Manzanita, Frijole and Choza Springs. The results of this study, shown in Table 126, indicated a good chemical water quality with no indication of human contamination of the springs.

## METHODS

### SAMPLE SITE SELECTION

The Guadalupe Mountains National Park has 11 known springs, 8 of which were included in this study. These springs--Bone, Guadalupe, Upper Pine, Smith, Manzanita, Frijole, Choza and Upper Dog Canyon--were selected because of their geographic distribution and the variation in degree of visitor use associated with each location (Figures 124-131). Upper Pine, Smith, Manzanita, Frijole and Choza are near the National Park Service visitor center and the Pine Spring campground. At the present time they receive the heaviest visitor use of any springs in the park. For example, Smith and Manzanita, which lie along the same trail were visited by 2,711 people during 1978 (National Park Service, 1978).

Upper Dog Canyon and Bone Springs receive very little use at the present time because of their remote locations. In 1978, 380 people

## TABLE 124. WATER QUALITY DATA ON McKITTRICK CANYON STREAM FROM STUDIES CONDUCTED BY O.T. LIND

| Parameter and Date | Sample Sites | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 7 |
| Temperature C | | | | | | |
| 5/69 | 26 | 20 | 18 | 20 | 21 | |
| 4/71 | | | 14 | | 14 | 16 |
| 11/72 | | | | | | 3 |
| pH | | | | | | |
| 5/69 | 8.7 | 8.5 | 7.7 | 8.0 | 8.3 | |
| 4/71 | | | 6.8 | | 7.5 | 7.5 |
| 11/72 | | | | | | 7.5 |
| Total Alkalinity (mg/L as $CaCO_3$) | | | | | | |
| 5/69 | 256 | 272 | 264 | 262 | 252 | |
| 4/71 | | | 250 | | 250 | 250 |
| Total Hardness (mg/L as $CaCO_3$) | | | | | | |
| 5/69 | 272 | 312 | 300 | 300 | 272 | |
| 4/71 | | | 270 | | 270 | 250 |
| Dissolved Oxygen (mg/L) | | | | | | |
| 5/69 | 6.0 | 7.0 | 8.0 | 6.5 | | |
| 4/71 | | 6.6 | | 9.0 | | |
| Specific Conductance @ 18C (micromhos/cm) | | | | | | |
| 5/69 | 450 | 350 | 490 | 480 | 300 | |
| Sulfate (mg/L) | | | | | | |
| 5/69 | 23.0 | 12.4 | 11.6 | 8.8 | 9.2 | |
| Nitrate-Nitrogen (mg/L) | | | | | | |
| 4/71 | | | 0.35 | | 0.10 | 0.10 |

Source: Lind, O.T., 1979. Limnology of McKittrick Creek, Guadalupe Mountains National Park, Texas. Symposium on Biological Investigations in the Guadalupe Mountains National Park, Texas. National Park Service Proceedings and Transactions Series Number Four, p. 125.

TABLE 125. WATER QUALITY DATA ON SPRINGS FROM STUDIES CONDUCTED BY O.T. LIND IN APRIL 1971

| Springs | Temp. C | pH | Total Alkalinity (mg/L as $CaCO_3$) | Calcium Hardness (mg/L as $CaCO_3$) | Total Hardness (mg/L $CaCO_3$) | Ortho Phosphate (mg/L) | Nitrate-Nitrogen (mg/L) | Sulfates (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Smith | 15 | 7.1 | 250 | 185 | 285 | 0 | 0.46 | 0 |
| Manzanita | 24 | 8.4 | 220 | 120 | 200 | 0 | 20 | 2 |
| Choza | 16 | 8.6 | 260 | 200 | 285 | 0 | 50 | 1 |
| Upper Pine | 15 | 8.2 | 260 | 185 | 260 | -- | 50 | 3 |

Source: Lind, O.T., 1971. A limnological analysis of McKittrick Creek and springs, Guadalupe Mountains National Park, Texas. Report to the National Park Service.

# TABLE 126. WATER QUALITY DATA ON SPRINGS FROM STUDIES CONDUCTED BY M. DICK

| Springs | Dissolved Oxygen (mg/L) | Temp. C | pH | Chloride (mg/L) | Conductivity (micromhos/cm) | Sulfate (mg/L) | Ortho Phosphate (mg/L) | Nitrate-Nitrogen (mg/L) | Total Suspended Solids (mg/L) | Total Hardness (mg/L as $CaCO_3$) | Fecal Coliform (colonies/100/mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Guadalupe | | | | | | | | | | | |
| 6/26/75 | 6.9 | 21 | 7.5 | 15 | 670 | 140 | < 0.03 | 1.30 | < 10 | 390 | -- |
| 7/18/75 | 5.5 | 17 | 7.6 | 10 | 680 | 142 | < 0.03 | 1.30 | 15 | -- | -- |
| 10/1/75 | 7.4 | 15 | 7.9 | 3 | 215 | 6 | < 0.03 | 0.60 | < 10 | -- | -- |
| Upper Pine | | | | | | | | | | | |
| 6/26/75 | 6.2 | 21 | 7.5 | 10 | 460 | 7 | < 0.03 | 0.56 | 14 | -- | -- |
| 10/1/75 | 7.4 | 15 | 7.9 | 3 | 215 | 6 | < 0.03 | 0.60 | < 10 | -- | 0 |
| Smith | | | | | | | | | | | |
| 6/26/75 | 7.7 | 17 | -- | 5 | 480 | < 5 | < 0.03 | 0.36 | < 10 | -- | -- |
| 7/18/75 | 7.3 | 16 | 7.3 | 10 | 480 | 6 | < 0.03 | 0.43 | < 10 | 310 | -- |
| 10/1/75 | 8.1 | 15 | 7.8 | 3 | 235 | < 5 | < 0.03 | 0.41 | < 10 | -- | 0 |
| Manzanita | | | | | | | | | | | |
| 6/26/75 | 14.7 | 24 | 8.3 | 5 | 310 | 10 | < 0.03 | < 0.02 | < 10 | -- | -- |
| 7/18/75 | 4.1 | 18 | 8.0 | 15 | 500 | 11 | < 0.03 | < 0.02 | 10 | 310 | -- |
| 10/1/75 | 8.7 | 14 | 7.8 | 3 | 190 | 11 | < 0.03 | < 0.02 | < 10 | -- | 0 |
| Frijole | | | | | | | | | | | |
| 6/26/75 | -- | 17 | 7.4 | 10 | 470 | 14 | < 0.03 | 0.59 | < 10 | -- | -- |
| 7/18/75 | 5.9 | 18 | 7.6 | 5 | 490 | 14 | < 0.03 | 0.60 | < 10 | 310 | -- |
| 10/1/75 | 6.0 | 17 | 7.1 | 3 | 230 | 13 | < 0.03 | 0.57 | < 10 | -- | -- |
| Choza | | | | | | | | | | | |
| 6/26/75 | 6.8 | 17 | 7.1 | 5 | 490 | 13 | < 0.03 | 0.59 | < 10 | -- | -- |
| 7/18/75 | 7.2 | 22 | 8.5 | 15 | 440 | 12 | < 0.03 | 0.32 | < 10 | 250 | 0 |
| 10/1/75 | 8.2 | 16 | 7.2 | 5 | 270 | 12 | < 0.03 | 0.59 | < 10 | -- | -- |

Source: Dick, M., 1975. Water quality analysis of six springs in Guadalupe Mountains National Park. Report to Texas Water Quality Board.

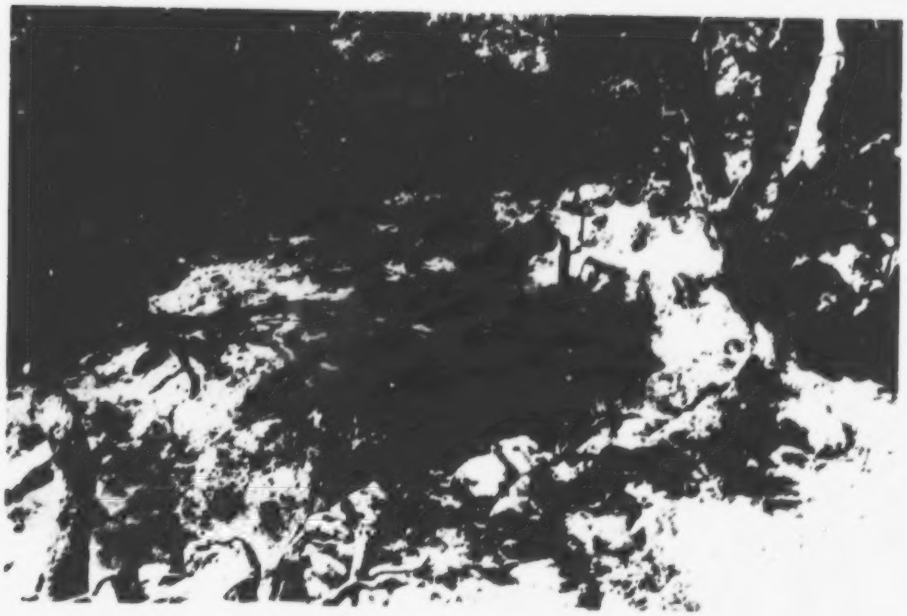


Figure 124. Upper Pine Spring.

Figure 125. Bone Spring.

Figure 126. Smith Spring.

Figure 127. Guadalupe Spring.

Figure 128. Manzanita Spring.

Figure 129. Frijole Spring.

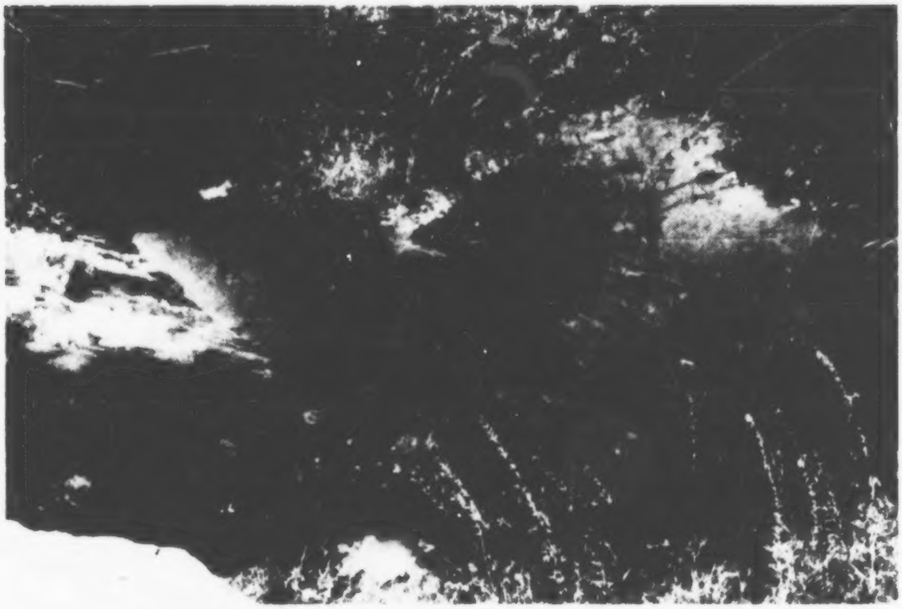


Figure 130. Choza Spring.

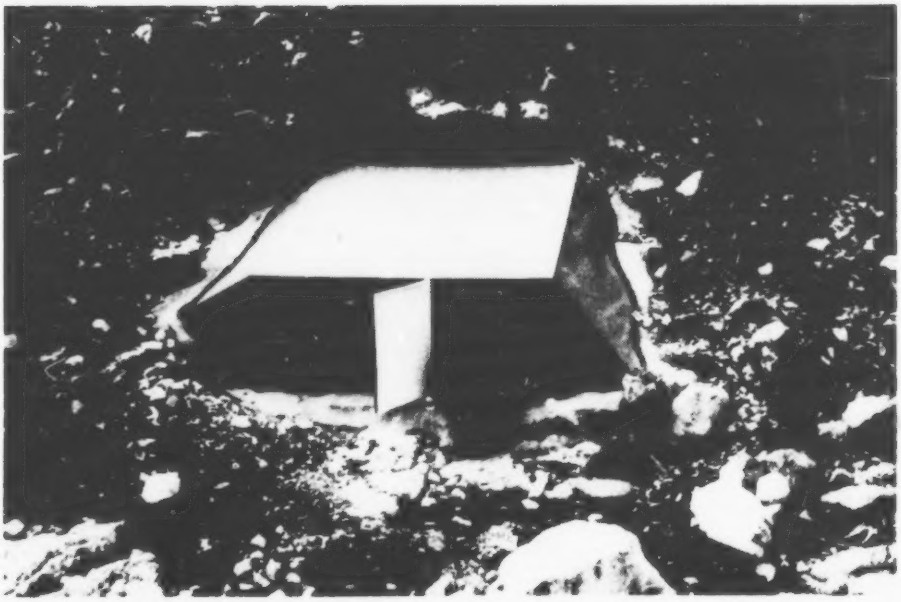


Figure 131. Upper Dog Canyon Spring.

visited the area around Bone Spring (National Park Service, 1978). As development of the roads into Dog Canyon and the Williams Ranch Historical area proceeds these areas will probably experience increasing use.

McKittrick Canyon Stream receives the heaviest visitor exposure of any water source in the park (Figures 132-143). In 1978, 8,321 people visited the McKittrick Canyon area (National Park Service, 1978). Main McKittrick Canyon extends from the National Park Service parking lot to the Pratt Lodge, at the confluence of North and South McKittrick Canyons. The trail from the parking lot to the Pratt Lodge is approximately 4 kilometers (2.5 miles)--a distance which usually discourages most visitors from travelling any farther. Hikers who go beyond the Pratt Lodge usually hike into South McKittrick Canyon because of its beauty and the flowing stream. South McKittrick is the second most heavily-visited area. Middle and North McKittrick Canyons do not have well-developed trails, have little flowing water and, thus, they receive light visitor use. Because of the visitor use and the surface stream, our water quality studies focused on Main McKittrick and South McKittrick Canyons.

Sample sites were selected to cover areas ranging from little human use to areas of heaviest human use. Sites 1 and 2 are in an area that receives minimum visitor use, because of its distance, approximately 8 kilometers (5 miles), from the parking lot. In 1978, approximately 728 people visited this area (National Park Service, 1978).

The Hunter Line Camp picnic ground in South McKittrick Canyon is a major stopping place for hikers. Site 3, picked as a control, is located slightly above the picnic ground. Site 4 is located just below the picnic site. In this way possible pollutants entering the water from the area of the picnic ground might be detected.

Site 5 is a pool just before the South McKittrick Stream goes underground for the first time. The stream flows underground for 100 meters and then flows above ground for 144 meters before going back underground. Site 6 is a small pool located just before this final surface flow in South McKittrick goes underground. Since these last two sites are situated along the trail up South McKittrick, sources of human impact on the water quality along this reach may come from non-point sources along the trail.

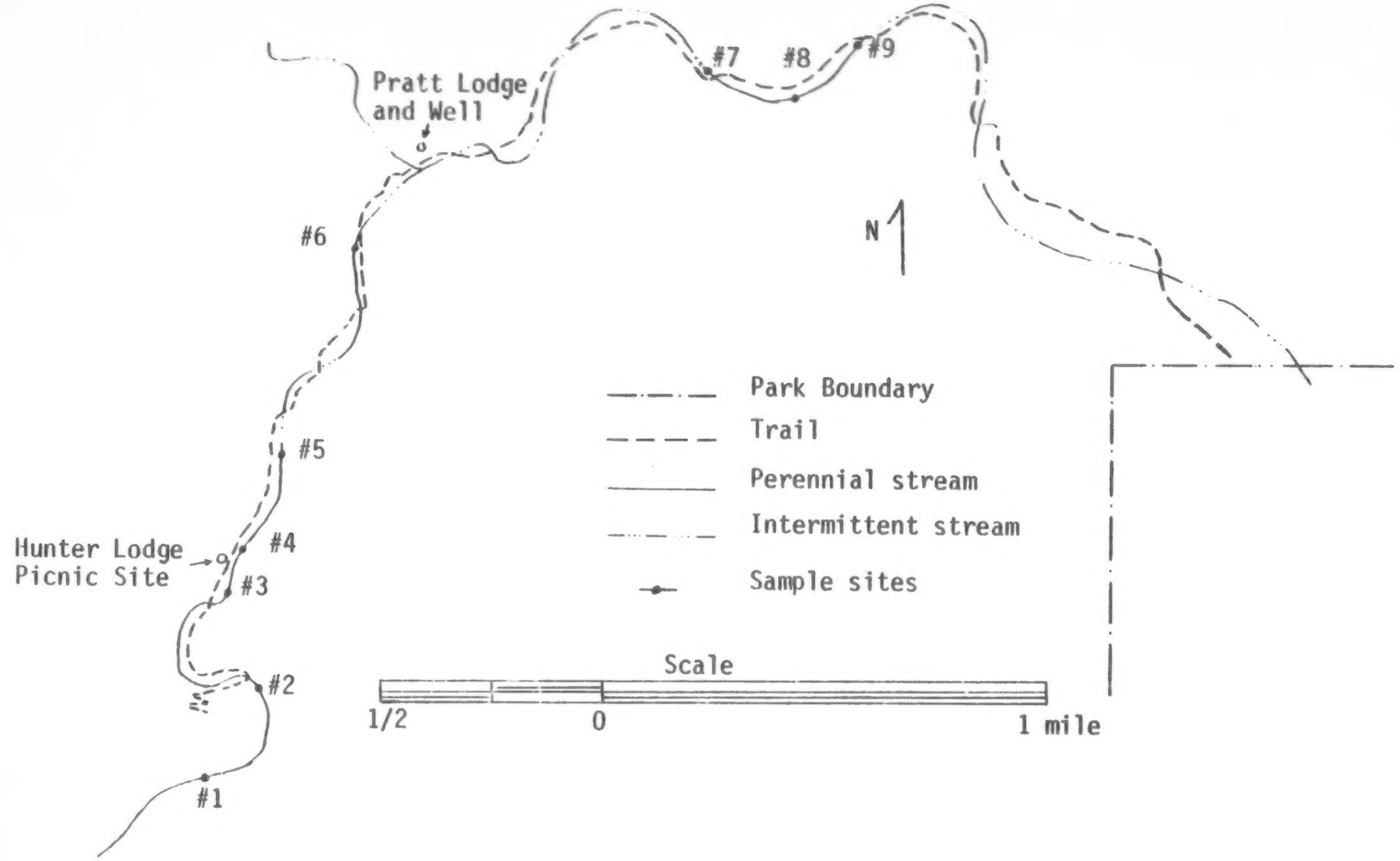


Figure 132. McKittrick Stream location of sample sites.

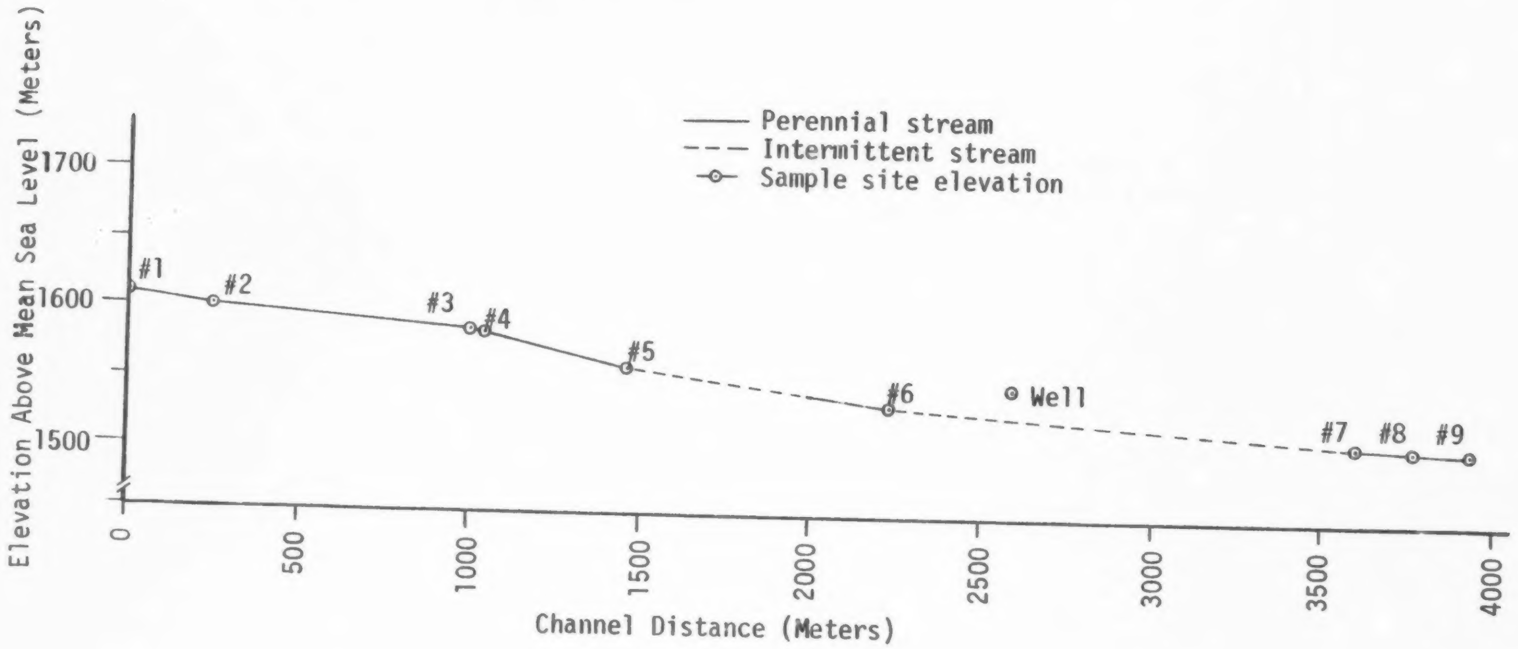


Figure 133. **McKittrick Stream Sample Site Elevations.**

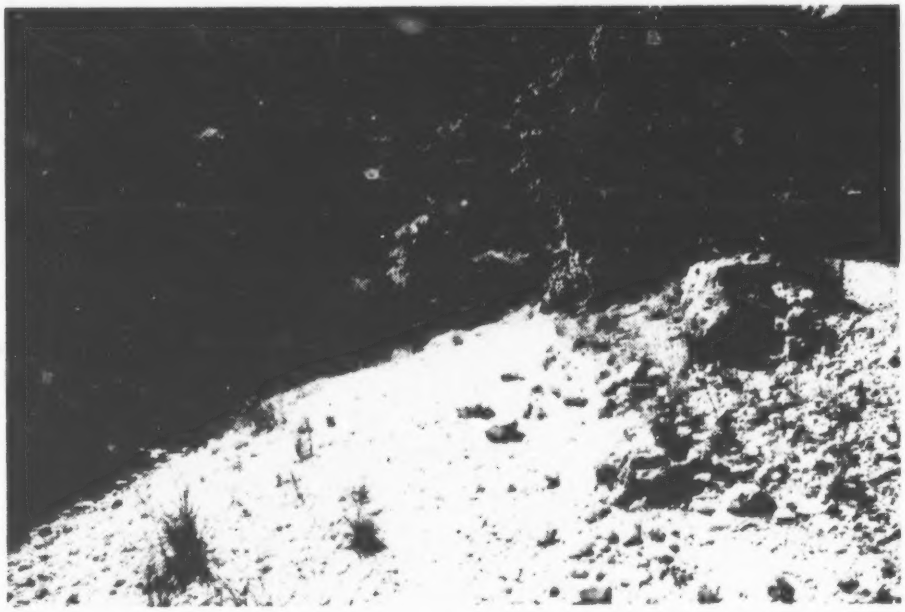


Figure 134. South McKittrick Stream--Sample Site #3.

Figure 135. South McKittrick Stream--Sample Site #1.

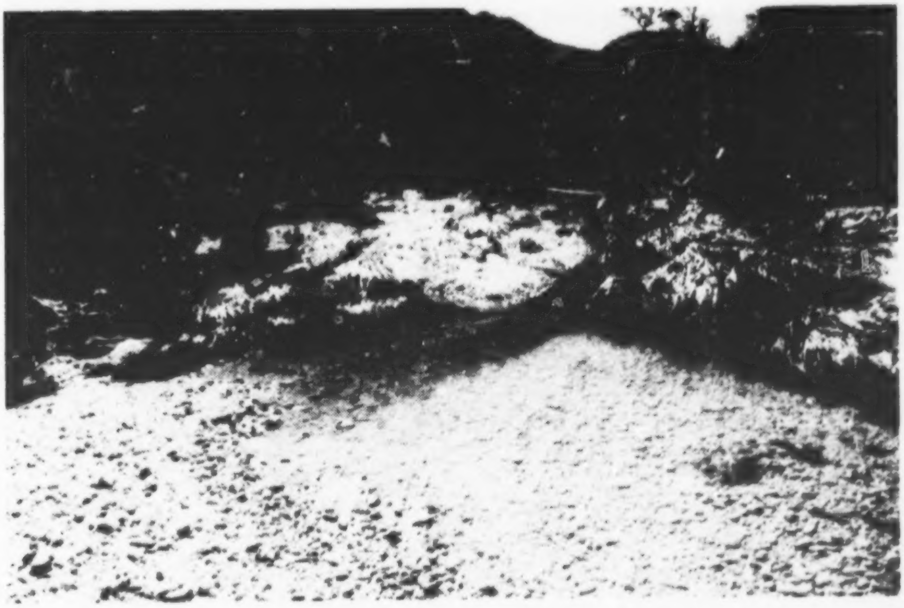


Figure 136. South McKittrick Stream--Sample Site #6.

Figure 137. South McKittrick Stream--Sample Site #2.

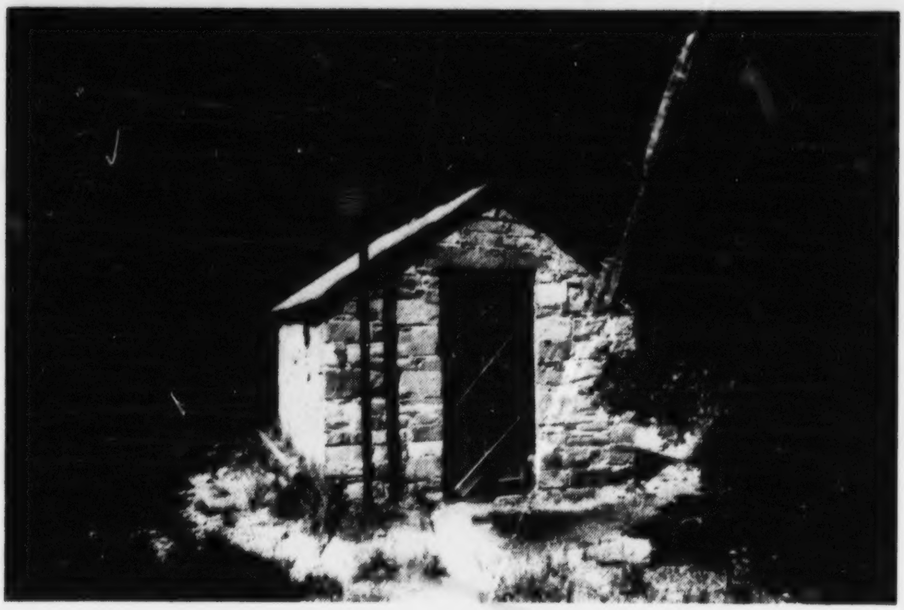


Figure 138. Pratt Lodge Well.

Figure 139. South McKittrick Stream--Sample Site #4.

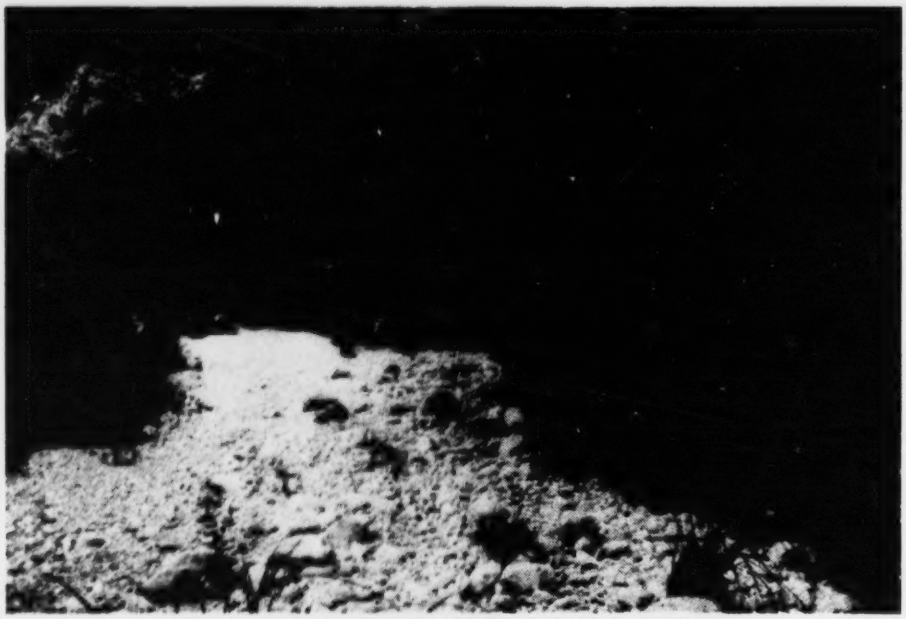


Figure 140. Main McKittrick Stream--Sample Site #7.

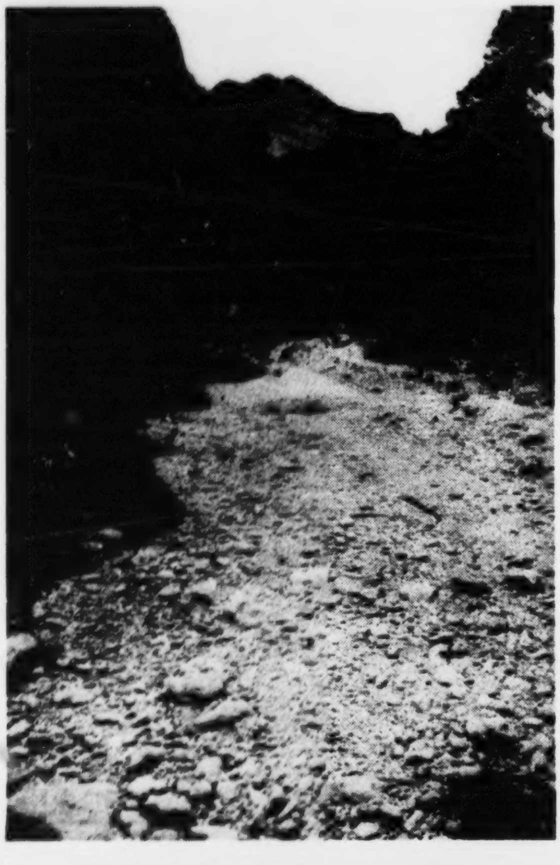


Figure 141. South McKittrick Stream--Sample Site #5.

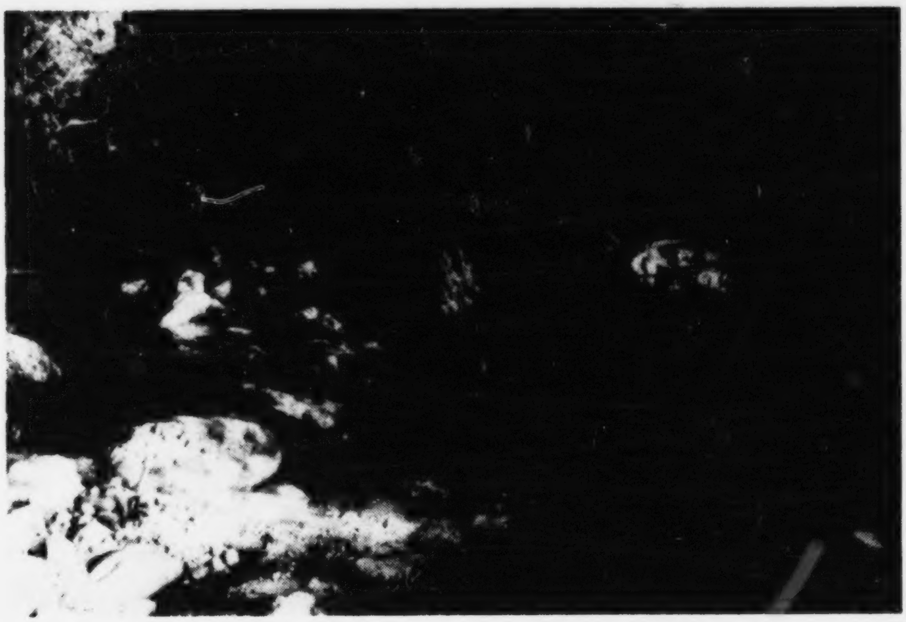


Figure 142. Main McKittrick Stream--Sample Site #8.

Figure 143. Main McKittrick Stream--Sample Site #9.

The well at the Pratt Lodge is below Site 6 and on a floodplain at the confluence of North and South McKittrick Canyons. It was included in this study because it is approximately 55 meters (180 ft.) from the Pratt Lodge cesspool (Figure 144).

Sites 7, 8 and 9 are located on the only surface reach of the stream in Main McKittrick Canyon. Since these sites are in the most heavily-used section of McKittrick Canyon, the water quality may be affected by overuse or misuse along the trail. The Pratt Lodge cesspool is upstream and may also contribute pollutants to the water.

## WATER QUALITY PARAMETERS

The parameters investigated in this study were selected to provide general information on the quality of water for aquatic life and for a drinking water supply. They would also indicate possible pollution from human impacts. Previous studies in the park measured some of these same parameters, thus permitting some comparisons of water quality over time.

Table 127 lists the methods and procedures used in the analysis of each parameter.

Water samples were collected in sterilized Mason jars or in one quart collapsible polyethylene containers, chemical oxygen demand samples in 50 ml amber glass vials and microbiological samples in 250 ml sterilized Malgelen polypropylene bottles.

Single "grab" or non-composited, unfiltered samples were taken at each sample site. Flow was not recorded for the sample sites at the time of sampling due to remoteness of the sites and restrictions on placing any permanent flow measuring device in the stream channel.

The Hach DR-EL/2* utilizes a direct reading spectrophotometer to measure concentrations of particular substances in water. The constituents are reacted chemically, and the color varies in intensity as a function of the constituent concentration. A variable interference light filter is used to adjust the wavelength of the light seen by the

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*The use of manufacturers names is intended solely for specific identification of equipment utilized and does not imply any form of endorsement by Texas Tech University or other agencies involved in this research.

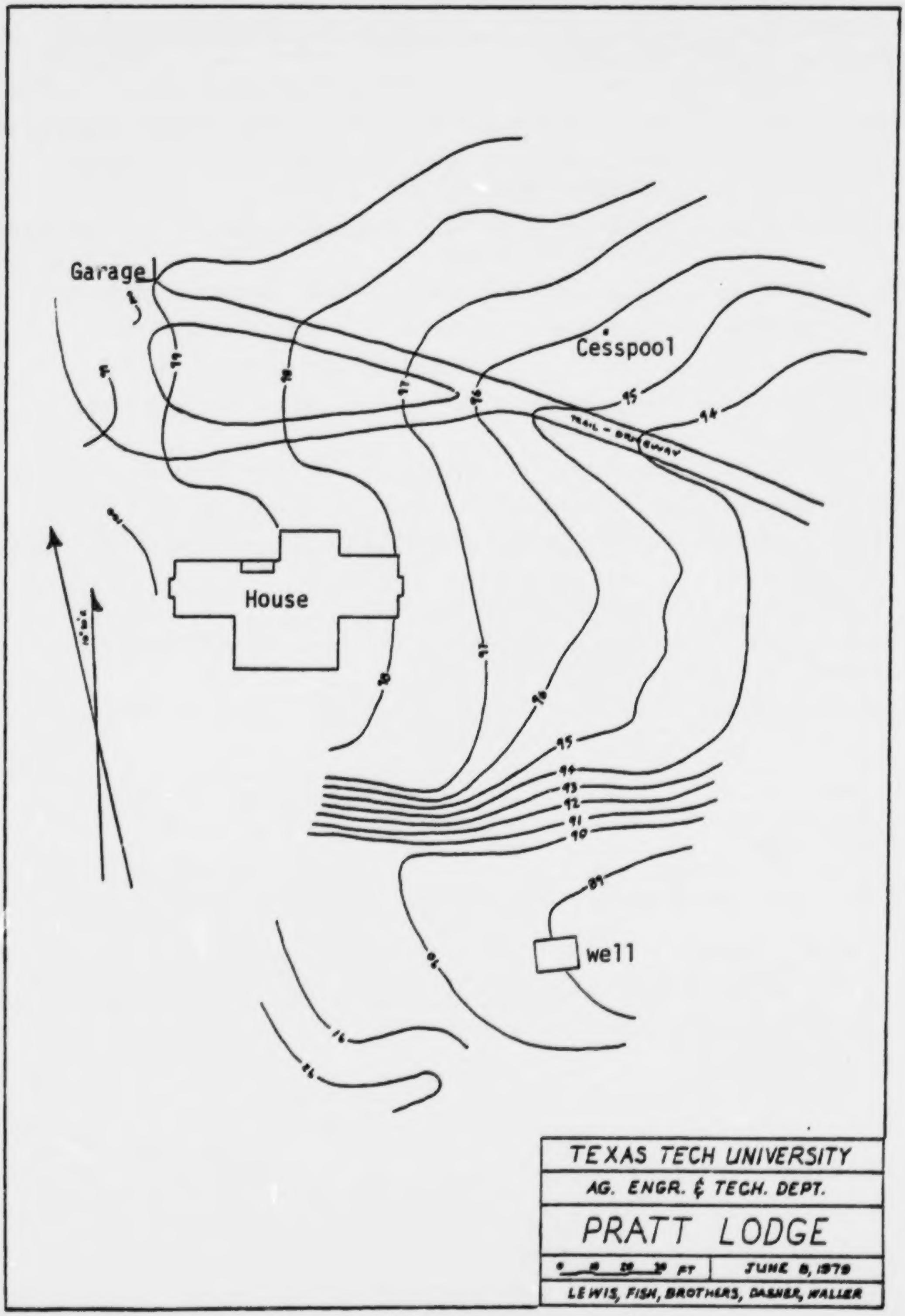

Figure 144. Topographic Map of the Pratt Lodge Area.

TABLE 127. WATER QUALITY ANALYSIS PROCEDURE

| Parameter | Procedures |
|---|---|
| Temperature C | Measured with a -20 to 100 celsius mercury thermometer |
| pH | Measured with a Hach #17200 or a NASA Instrument Company #49 pH meter |
| Dissolved Oxygen | Measured using *Hach Chemical Company's Winkler-Azide Titration Method |
| Nitrate-Nitrogen | *Hach Chemical Company's Cadmium Reduction Method |
| Orthophosphate | *Hach Chemical Company's Ascorbic Acid Method |
| Sulfates | *Hach Chemical Company's Turbidimetric Method |
| Chlorides | *Hach Chemical Company's Mercuric Nitrate Titration Method |
| Total Hardness | *Hach Chemical Company's Titration Method |
| Calcium Hardness | *Hach Chemical Company's Titration Method |
| Total Alkalinity | **Standard Methods, 14th Ed. Potentiometric Titration |
| Total Suspended Solids | **Standard Methods, 14th Ed. |
| Chemical Oxygen Demand | **Standard Methods, 14th Ed. Dichromate Reflux Method (low-level) |
| Total Coliforms | **Standard Methods, 14th Ed. Total Coliform Membrane Procedure |

Source: *Hach Chemical Company. Methods manual for Hach direct reading engineer's laboratory model DR-EL/2. 1st Ed. Hach Chemical Company, Ames, Iowa.

**American Public Health Association, Washington, D.C., 1971. Standard methods for examination of water and wastewater. 14th Ed.

Note: Preservation technique used was refrigeration to 4C. Nitrate-nitrogen and orthophosphates were usually run within 8 hours of collection. Total coliforms were run within 48 hours of collection. The rest of the parameters were run within 7 days.

photocell. The DR-EL/2 uses insertable meter scales which are calibrated to provide direct readout of each constituent concentration. Although the results obtained from such an analysis are generally less accurate than those obtained from a precise laboratory analysis, such procedures generally give good results if the sampled water is relatively clean.

The Hach DR-EL/2 spectrophotometer has a wavelength range of 400-700 nm and a wavelength accuracy of ± 2.5 nm. It has a wavelength reproducibility of ± 1.0 nm, a photometric accuracy (using 100% T scale) of ± 2.5 nm and a photometric reproducibility of ± 1% (Hach, undated).

The coliform group is used as an indicator of contamination by warm-blooded animals. While the fecal coliform bacteria are not themselves pathogenic, their presence in water indicates recent and possibly dangerous contamination by warm-blooded animals, including man. The presence of the other coliform organisms indicates less recent pollution from other sources of non-fecal origin, such as soil runoff water.

Samples were collected, labeled and stored on ice until laboratory tests could be performed. The inaccessibility of the water resources with respect to each other, and the distance from the collection points to the laboratory promoted the use of two procedures.

The microbiological analysis utilized the millipore filter procedure in which samples are filtered and placed on a growth medium for incubation and detection. Normally, the samples are returned to the laboratory where they are filtered, placed on the growth medium, and incubated--all within a short period of time.

In those cases where a laboratory is not readily available and the samples must be stored for a time longer than is desirable a delayed incubation procedure is used. This procedure involves immediate filtration of the sample. The filter is then placed on a holding medium which keeps the bacteria alive but prevents their growth. Upon return to the laboratory the filter is transferred to the growth medium for incubation. Membrane filters with a pore diameter of 0.45 nm were utilized.

Sample volumes of 10, and 50, and 100 ml were filtered for each source. Sterile dilution water was used to rinse the filtration apparatus between filtrations. For the direct incubation procedure, the membrane filters were placed in plastic disposable petri dishes on absorbent pads containing 1.8 to 2.2 ml of M-Endo medium. The petri dishes were then incubated for 24 hours at 35C. For the delayed incubation procedure, the initial medium was N-Endo preservative medium, which is identical to M-Endo medium except for the addition of a sodium benzoate solution which prevents bacterial growth. Upon arrival at the laboratory, the filters were transferred to M-Endo medium for incubation at 35C for 24 hours.

Following the incubation period, the colonies were counted on each of the filters. Typical coliform colonies on M-Endo medium have a pink to dark red color with a metallic surface sheen. Coliform densities in terms of coliforms/100 ml were determined by:

$$\text{Total coliforms/100 ml} = \frac{\text{coliform colonies counted X100}}{\text{ml sample filtered}}$$

## RESULTS AND DISCUSSION

The following discussion will review the results of the water quality parameters and future and/or present problems at each of the sample sites. Complete data on all samples is contained in Appendix C.

### SPRINGS

Nitrate-nitrogen and orthophosphate averages were 0.45 mg/l and 0.09 mg/l, respectively. These averages are above the limiting values established for algal growth. Limiting values are taken to be approximately 0.3 mg/l for inorganic nitrogen and 0.01 mg/l for inorganic phosphorus (Ferguson, 1968).

Guadalupe Spring, with an average of 0.88 mg/l, exhibits the highest nitrate-nitrogen level of all the water sources studied in the park. This observation also occurred in a previous study in which the average nitrate-nitrogen level was 1.07 mg/l (Dick, 1975). Since this spring receives very little human use and is not near any campsites, it is unlikely that the nitrate-nitrogen input is from human sources. The probable answer may be related to the presence of nitrogen-fixing bacteria or the geological nature of the aquifer, but neither of these ideas has been verified at the present time.

Manzanita Spring, with an average of 0.21 mg/l, has the highest orthophosphate average of all water sources studied in the park. As the nitrate-nitrogen, chloride, total coliform and fecal coliform levels were low it seems unlikely that the orthophosphates were contributed by human sources. Manzanita Spring is the largest spring in the park and is in an open area. The sample site was in a shallow area (15 centimeters) and sediment could easily be disturbed by wind-induced currents. One high reading of 1.3 mg/l orthophosphate caused the average to be much higher than the other springs.

As aerobic biological decomposition of organic matter uses dissolved oxygen, any dissolved oxygen levels that are significantly below the saturation level may indicate organic pollution. At the springs studied dissolved oxygen was usually at or near saturation value. In a few of the springs supersaturation of dissolved oxygen was observed. Photosynthetic activity was the likely cause of this supersaturation. Measurements were usually made in the afternoon. The diurnal variation in dissolved oxygen levels, caused mainly by plant photosynthesis, was not specifically studied but it does not appear to be of much significance under the natural conditions occurring in the springs.

Results for total suspended solids, chemical oxygen demand, total coliforms and fecal coliforms indicate a water of high quality. For total suspended solids 75.8% of all samples measured were less than 10 mg/l while 87.9% were less than 20 mg/l. The highest total suspended solids reading of 36 mg/l was obtained at Upper Dog Canyon Spring. The reading was obtained after the pool at the spring house had recently been pumped to the ranger station, thus sampling the spring pool just as it started refilling. Chemical oxygen demand results for all the springs show that 71% of the readings were less than 5 mg/l while 86% of the readings were less than 10 mg/l. The highest chemical oxygen demand level was 16 mg/l which was recorded at Manzanita Spring. Total coliform data averages 17.3 per 100 ml for all the springs. In an earlier study by Dick (1975) and twice during this study (October, 1977 and March, 1979) fecal coliforms were run with negative results recorded at the springs.

Water sources on the west side of the park exhibit an increase in mineralization when compared with water sources on the east side. Upper

Pine, Smith, Manzanita, Frijole and Choza Springs are in the same general area along the eastern escarpment. They exhibit similar mineralization as shown by specific conductance readings (Figure 145).

Manzanita Spring exhibited the lowest averages of total hardness, calcium hardness and total alkalinity of these 5 springs. This spring has the largest exposed surface area of any spring and the greatest amount of aquatic plant growth. Due to the photosynthetic activity, carbon dioxide is depleted, and thus, the pH rises, causing calcium carbonate to precipitate as the calcium carbonate solubility product is exceeded. This may be the main reason that Manzanita Spring has the lowest total hardness, calcium hardness and total alkalinity readings.

Moving south and west toward Guadalupe and Bone springs, an increase in mineralization is also shown by increases in total hardness, calcium hardness, chlorides and sulfates. The most likely cause of these increased readings is that the southwestern and western portions of the park contain many of the evaporative sediments of the ancient backwater lagoon.

## McKITTRICK CANYON STREAM

A general trend for the parameters of total hardness, calcium hardness, total alkalinity and specific conductance to increase exists as the flow moves downstream. The most likely reason for this increase is the dissolution of calcium carbonate from the stream bed as the stream flows underground between breaks in the travertine. Examples of this trend are the increases between Sites 5 and 6 and between Sites 6 and 7. The stream goes underground at Site 5 and resurfaces at Site 7.

Nitrate-nitrogen shows a general, but small, increase as the flow moves downstream. A partial cause for this increase may be due to the "downhill" movement of organic matter in a watershed. Deciduous trees increase in number below the Hunter Line Camp, down South McKittrick Canyon and into McKittrick Canyon until the desert communities are reached. The organic detritus left by the autumn leaf fall would then also contribute to the general increasing nitrate-nitrogen trend. A substantial increase in nitrate-nitrogen, specific conductance, total hardness and calcium hardness is noted after the stream leaves South

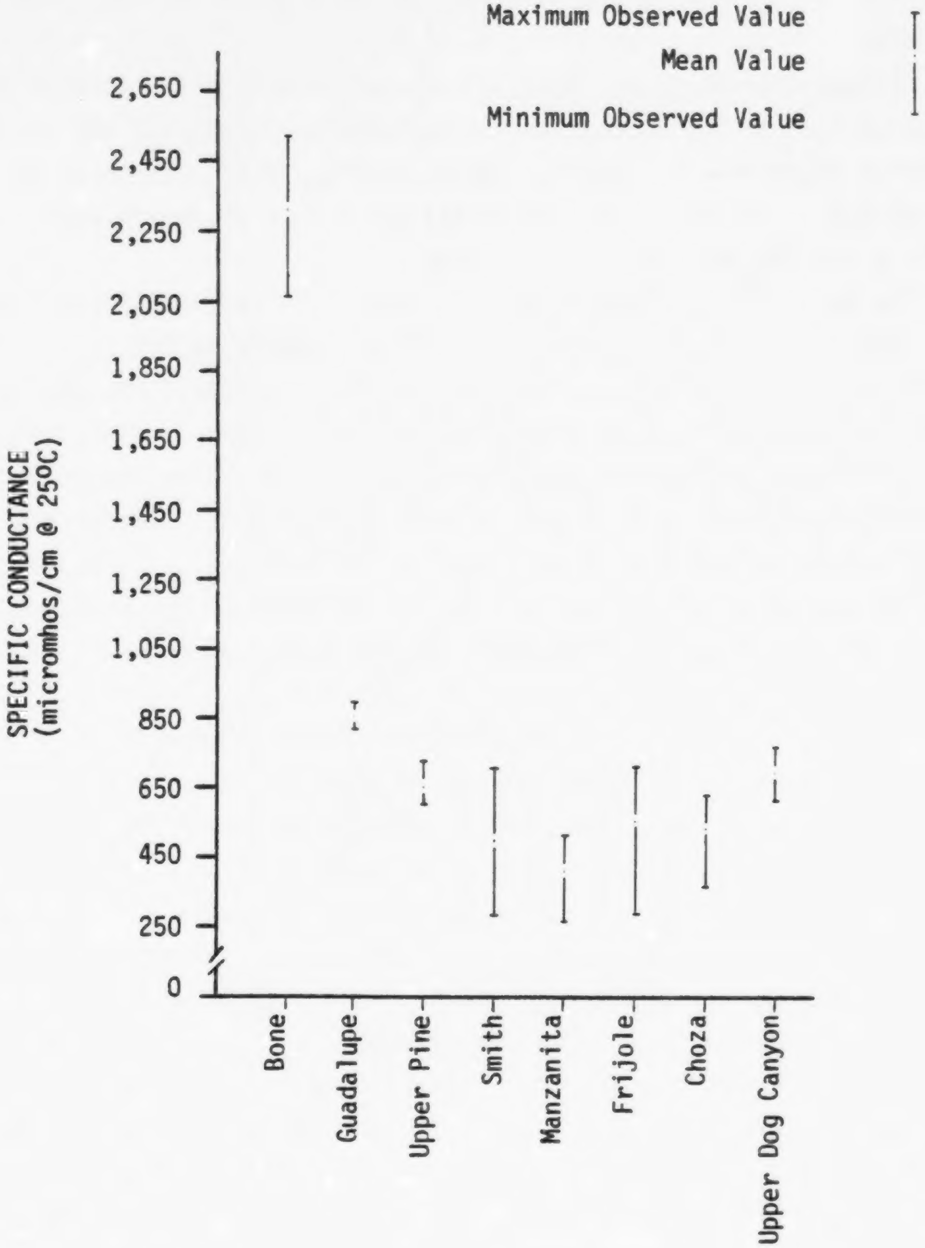

Figure 145. Specific conductance levels for the springs.

McKittrick Canyon and enters McKittrick Canyon. This may be caused by the mixing of groundwaters at the confluence of South and North McKittrick Canyons.

Orthophosphates do not seem to show the same general increase downstream as some of the other chemical parameters, because of the rapid uptake of phosphorus by aquatic plants, absorption of phosphorus by particulate matter and the precipitation of soluble phosphate with metallic ions in the water (Keup, 1968).

The possibility existed that the cesspool at the Hunter Line Camp was contributing nitrate-nitrogen and orthophosphate to McKittrick Canyon Stream (Lind, 1971). The restroom facilities and cesspool at the Hunter Line Camp picnic ground were closed in 1970. Since this 1970 closure, the situation seems to have improved. The chemical parameters mentioned showed a slight increase between Site 3, above the picnic ground, and Site 4, which is below the picnic site. Because these increases are small and the chemical parameters mentioned tend to increase as the stream progresses, no definite indication of nutrient addition by the cesspool is shown.

The Pratt Lodge well had an average nitrate-nitrogen level of 0.31 mg/l with an average chloride level of 2.8 mg/l which are the highest recorded levels for the sites along McKittrick Stream. The increase in these parameters may be caused by the cesspool (Figure 144). During the period from April 22, 1979, to June 17, 1979, average influent to the cesspool was 1,119 gallons per week. Some of this influent may be used in evapotranspiration by the many trees in the area along with an unknown amount of dilution of the influent by groundwater. Tests for total coliform were run on the well with negative results. These negative total coliform results were expected, because the well is over 55 meters (180 ft.) from the cesspool. As the distance through the ground increases, especially over 31 meters (100 ft.), the number of bacteria, such as coliforms, are quickly reduced to near zero (McGauhey, 1968).

Dissolved oxygen and pH levels are fairly constant from one sample site to the next. Dissolved oxygen usually occurs at or near saturation level throughout the stream. Since the dissolved oxygen levels were taken only at midday, no diurnal variations were studied. The conditions of the stream's aquatic population seems to indicate that the diurnal variations do not cause any problems. The pH is on the basic side, averaging around 7.5, which at this level does not represent a threat to the aquatic population.

Stream temperature, which can be harmful to aquatic life above or below certain limits, does not show a normal increase as the flow moves downstream because of the discontinuous nature of the stream. Trout can tolerate temperatures up to 28C, and were commonly found along the stream. The highest temperature reached during the summer was 27C at Site 6. There were no trout present in the shallow pool at Site 6.

Total coliforms, total suspended solids, chemical oxygen demand and chloride levels indicate water of high quality. Total coliforms averaged 28.1 per 100 ml with a high of 114 per 100 ml. This compares to levels of 1000 total coliforms per 100 ml usually allowed in public drinking water supplies. Total suspended solids are low with 66% less than 10 mg/l and with the highest at 32 mg/l. Chemical oxygen demand is low with 27% less than 5 and the rest under 10 mg/l. Chlorides are low, under 5 mg/l each. The State of Texas has set a secondary standard level of 300 mg/l on chlorides.

## CONCLUSIONS

The chemistry of the water in the Guadalupe Mountains National Park reflects the sedimentary geology of the region. Typically the water reflects a well-buffered calcium carbonate-magnesium carbonate system. The principle ion is usually bicarbonate, while sulfate is the second most prevalent anion. These results are within the expectations of comparison for water chemistry data from different areas of sedimentary deposits. Nutrient levels of nitrate-nitrogen and orthophosphate, while above limiting levels for algal growth, do not appear excessive considering the natural inputs, such as autumn leaf litter, of the area.

Water quality data collected in this and previous studies indicate that recreational use at the present time is not significantly affecting or degrading the water quality of the springs.

The water quality data collected in this study and a previous study by Lind (1979), suggests that recreational use is having an impact on water quality in McKittrick Canyon Stream. In Lind's study, the cesspool at the Hunter Line Camp picnic ground was a possible source of pollutants to the stream. As stated previously, this cesspool has been closed for 9 years and no longer appears to be contributing pollutants to the stream. At the present time, the actively-used cesspool at the Pratt Lodge may represent a present and certainly a future source of pollutants to the McKittrick Canyon Stream.

# CHAPTER IX SURFACE HYDROLOGY AND EROSION

## INTRODUCTION

Chapter III ("Watershed Inventory Studies") revealed that watersheds originating within the park drain either into the Salt Flats Basin or into the Delaware Creek or Black River which flows into the Rio Grande via the Pecos River.

Watersheds which drain into the Salt Flats Basin are those on the west side of the park, as well as those which drain north and south from the park. Their channels often begin at high elevations with very steep gradients, and the channels increase in size and capacity as they approach the edge of the mountains. On the west side of the park many of these channels carry storm runoff out of the mountains abruptly onto bajadas of alluvium, and thence on to the desert floor eventually to collect in salt lakes. As runoff flows in the channels across the bajadas, rapid seepage occurs into the alluvium through unconsolidated materials making up the channel bottom. Channel size and capacity decreases from the mountains to the desert floor. In many instances drainageways lose all character, and defined channels disappear before the alluvium is crossed and a defined lake bed is reached.

Watersheds which drain into the Delaware Creek or Black River are those on the east side of the park, as well as those which drain the central high country. Their initial channels are similar to those on the west side of the park. However, they do not lose their character after they have left the mountains but continue as defined channels.

It is suspected that the bottoms of many of these channels are underlain by consolidated material (limestone or travertine) which greatly reduces seepage loss.

## FIELD SURVEYS

A profile survey was performed on certain channels within each watershed selected for intensive investigation to establish a baseline data for future use. Each survey established the present ground profile perpendicular to the direction of flow (giving a cross-section view), and for most locations, the profile parallel to the direction of flow for short distances upstream from the cross-section location. The location of each cross section was monumented allowing for resurvey in the future and determination of any changes.

The primary channel(s) of each selected watershed was/were surveyed at or near the park boundary. The larger watersheds were subdivided into their major sub-watersheds, and the main channel of each sub-watershed was also surveyed. Survey locations were numbered within each watershed. Figures 146-150 show the survey locations for each watershed. The drainage area of the watershed above each survey location was outlined on a 7.5 minute Geological Survey map and its size was determined using a polar planimeter.

At each survey location, a steel stake was driven into the ground at each end of the cross-section profile line to monument the location. Each monument was placed so as not to attract attention, except in remote areas which were not likely to be visited by the general public. In many cases the steel stake was hidden from view by a rock cairn. Photographs/slides were taken at each survey location showing the present appearance of each monument. The photographs/slides also show the location of each monument relative to local landmarks and to the horizon. Figures 151-153 illustrate a monument and the pictorial record obtained. A complete set of photographic records and associated field notes is filed with the Park Headquarters and at Texas Tech University for reference purposes.

The data collected consisted of standard profile data along a straight line, magnetic azimuth of cross-section profile lines, and miscellaneous comments. Standard profile data along right angle offsets

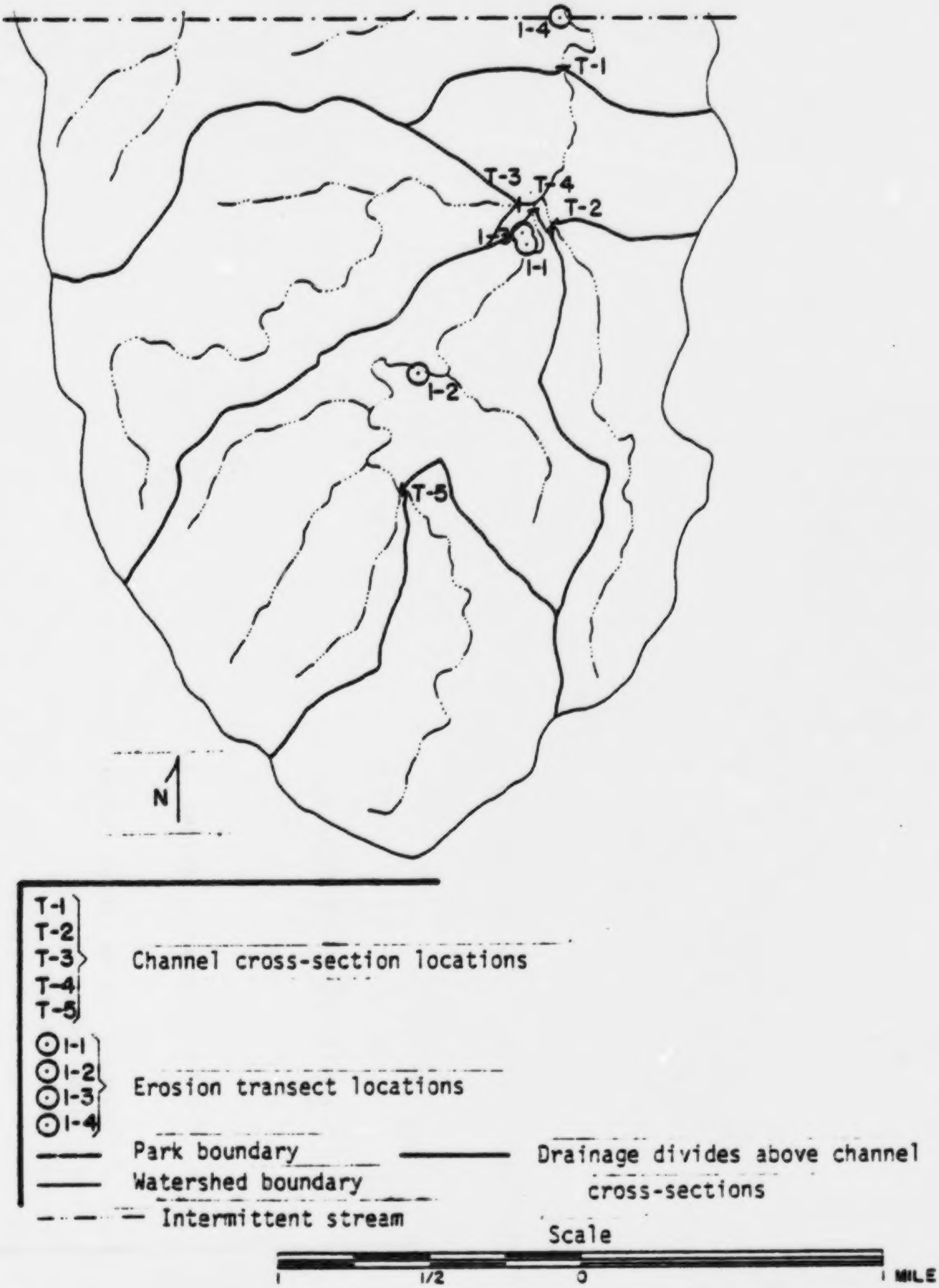

Figure 146. Transect and cross-section locations--Watershed 1.

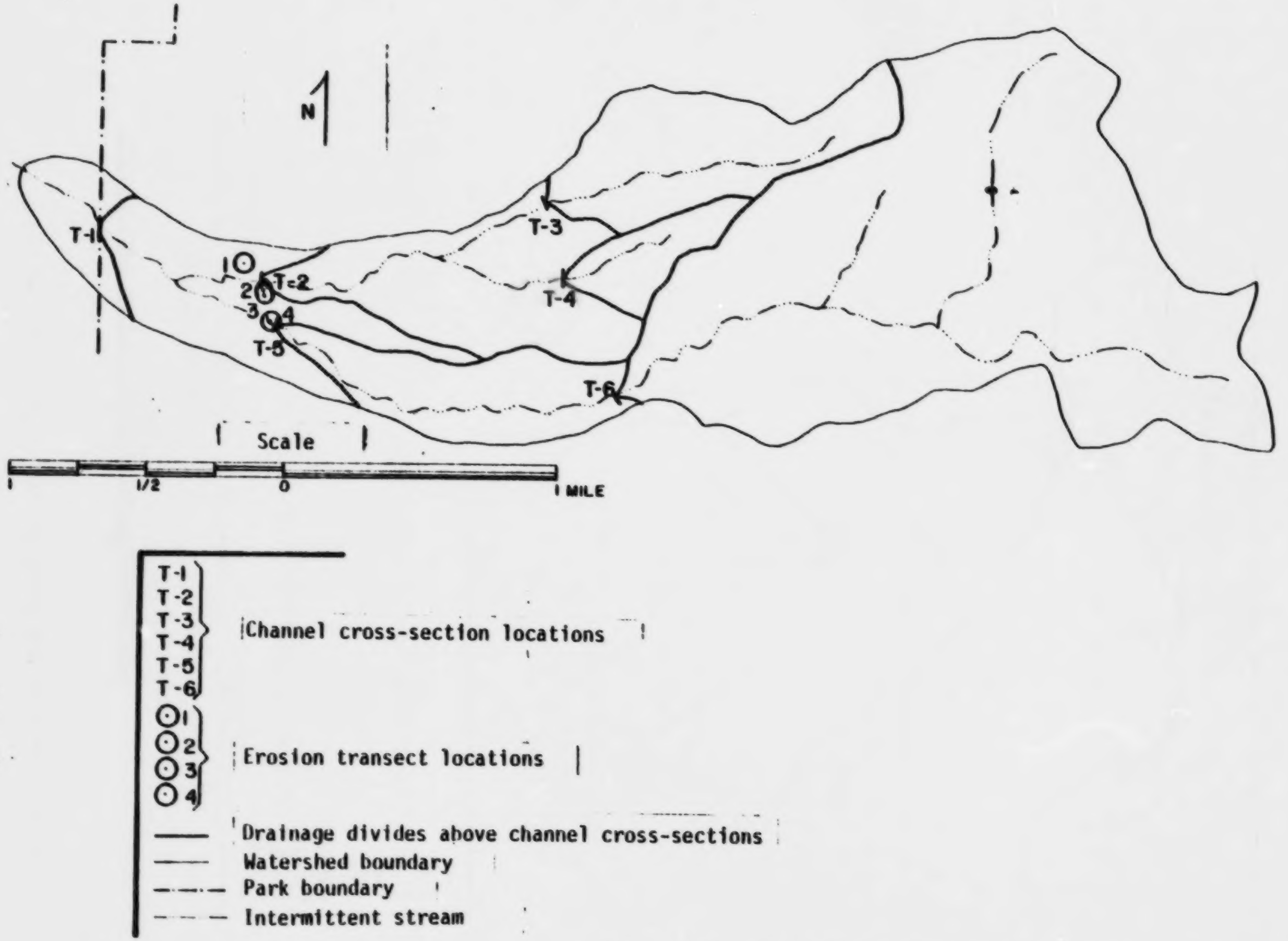

Figure 147. Transect and cross-section locations--Watershed 10A6.

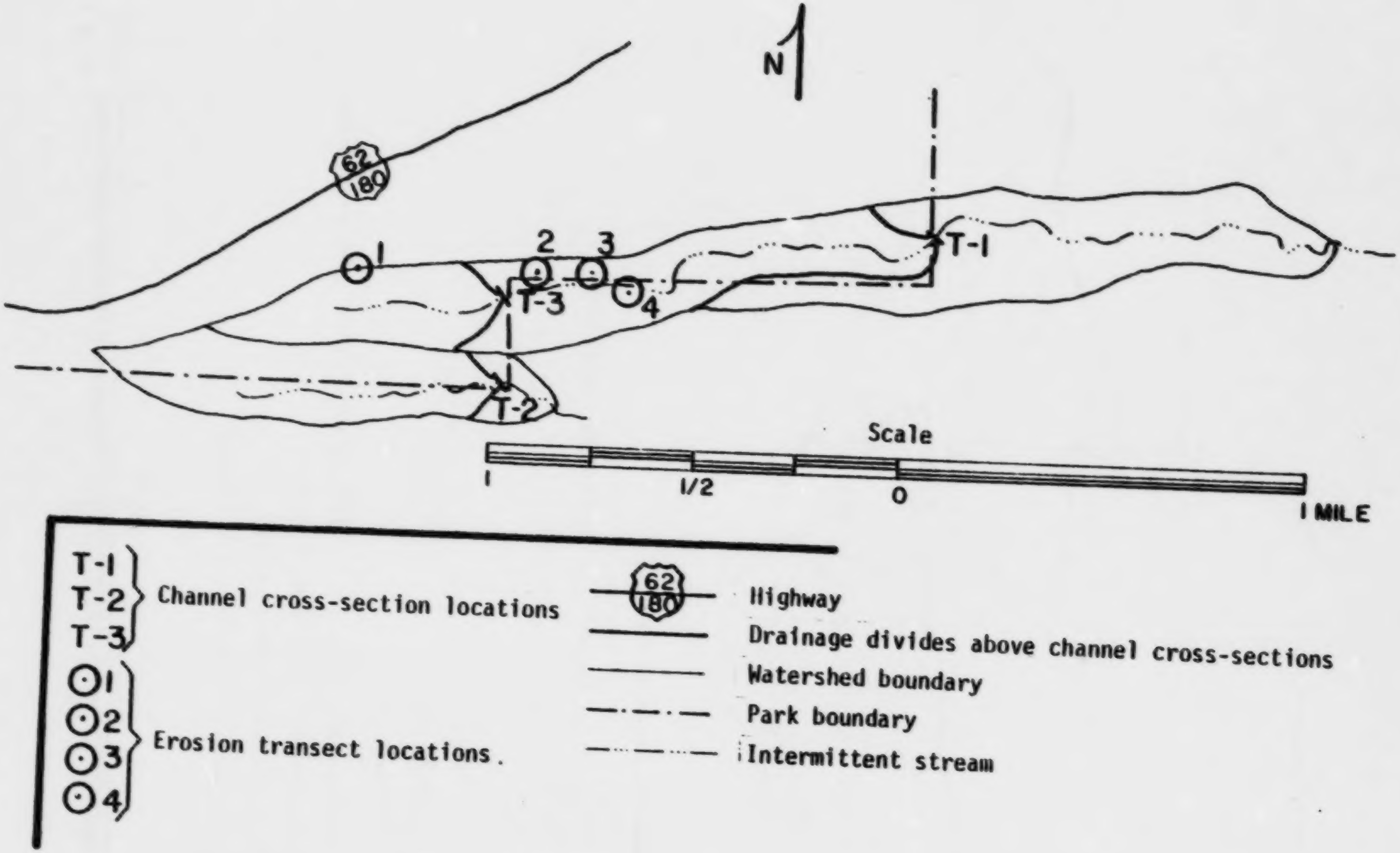

Figure 148. Transect and cross-section locations--Watershed 8B-8D.

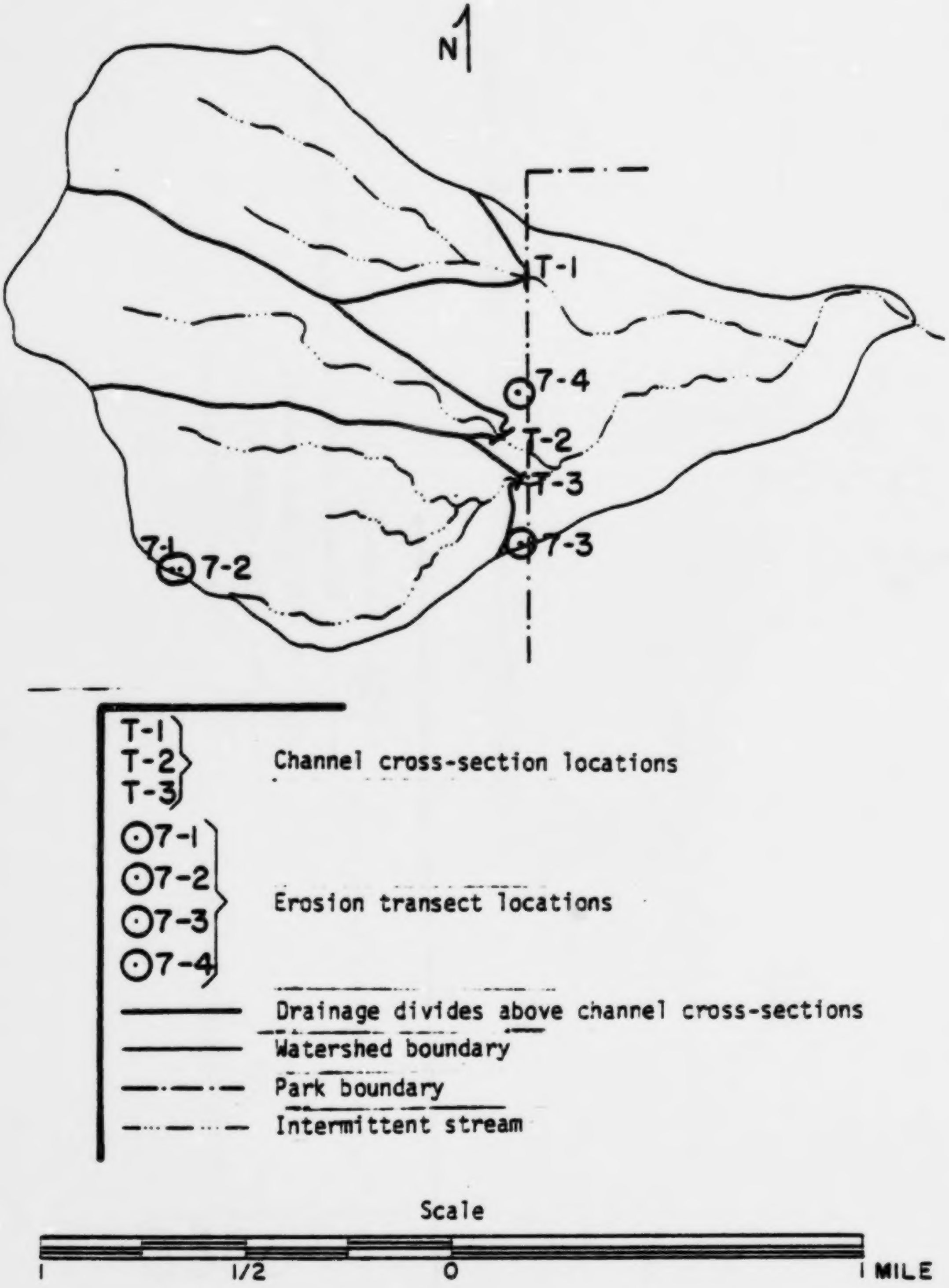

Figure 149. Transect and cross-section locations--Watershed 7.

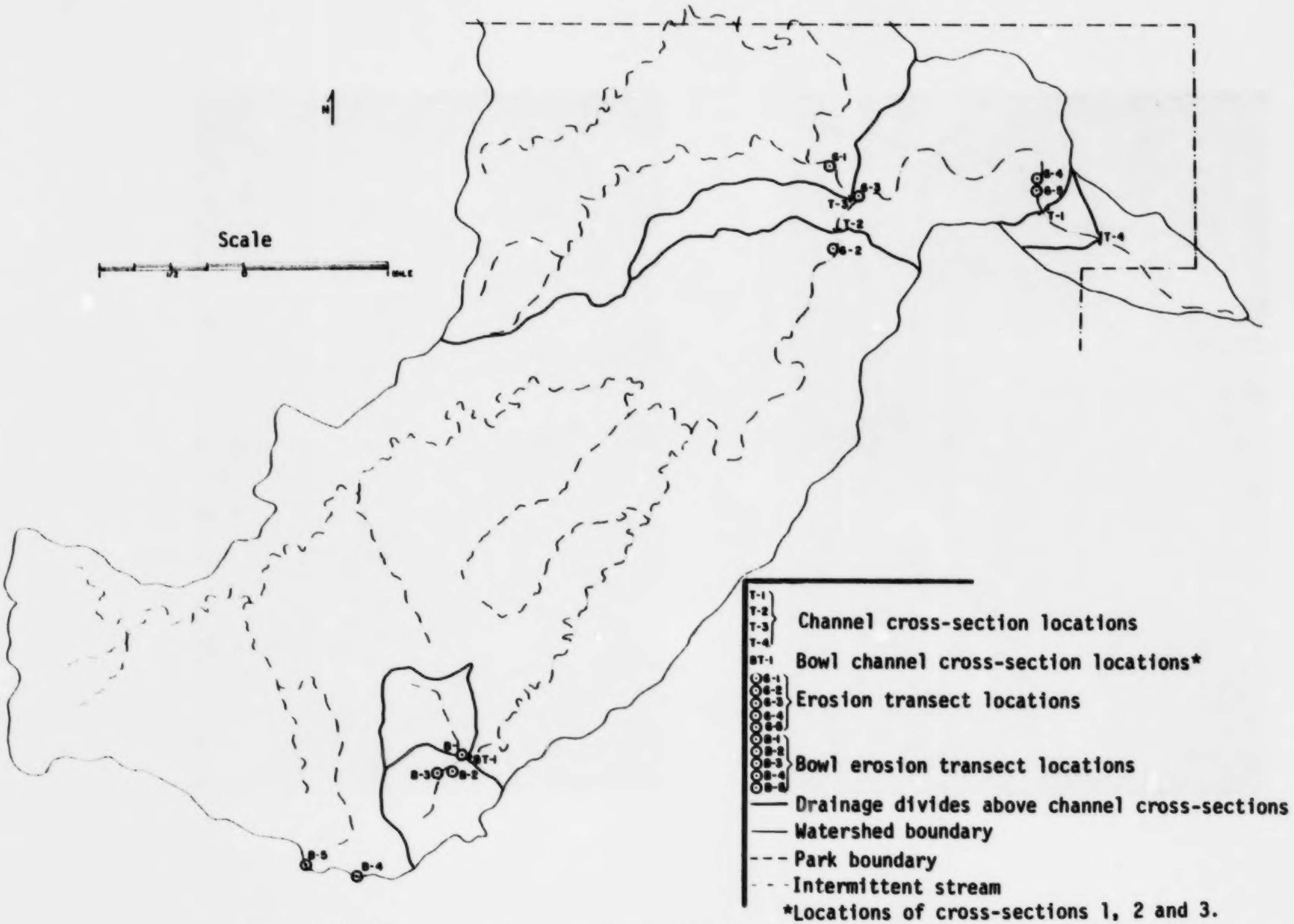
N
Scale
1/2
0
1 MILE
6-1
6-2
6-3
6-4
6-5
T-1
T-2
T-3
T-4
BT-1
B-1
B-2
B-3
B-4
B-5
T-1
T-2
T-3
T-4
Channel cross-section locations
BT-1
Bowl channel cross-section locations*
6-1
6-2
6-3
6-4
6-5
Erosion transect locations
B-1
B-2
B-3
B-4
B-5
Bowl erosion transect locations
Drainage divides above channel cross-sections
Watershed boundary
Park boundary
Intermittent stream
*Locations of cross-sections 1, 2 and 3.

Figure 150. Transect and cross-section locations--Watershed 6.

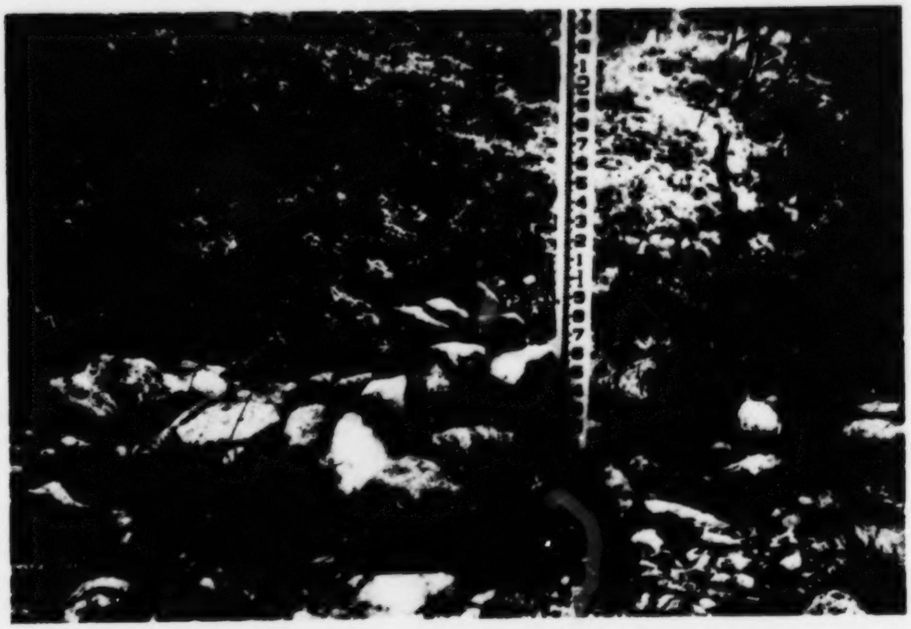

Figure 151. Rock cairn around survey monument, Watershed 1, Location 2.

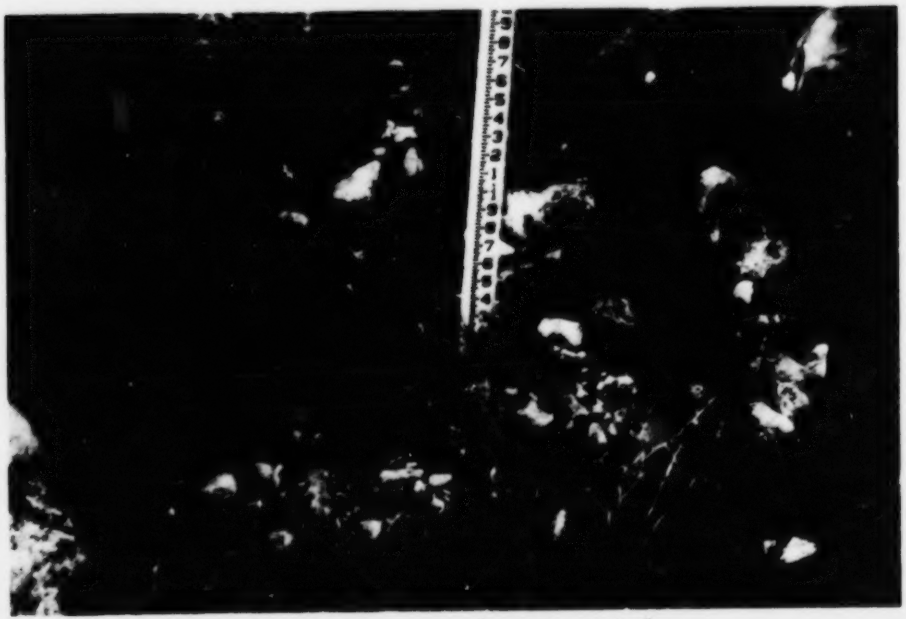

Figure 152. Survey monument (steel stake), Watershed 8B, Location 2.

Figure 153. Survey monument (at level rod), Watershed 8B, Location 2.

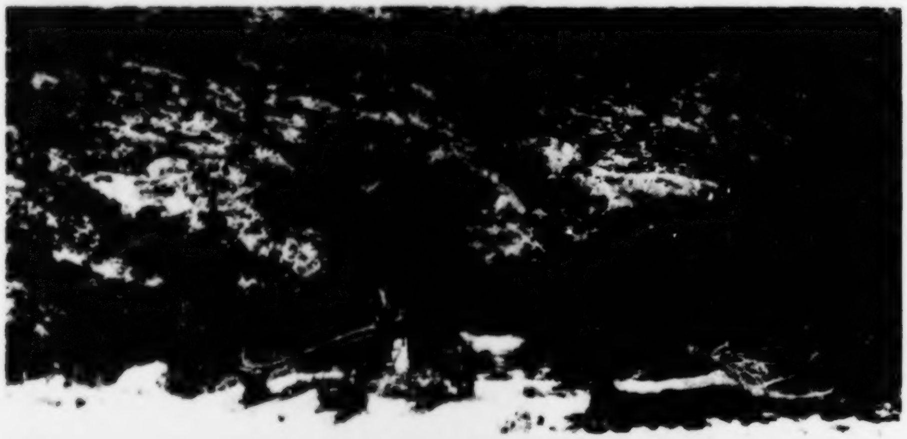

Figure 154. Flood debris in McKittrick Canyon. Debris at right is from 1978 storm. Debris in tree at center is from a previous storm.

were also collected at some locations. The data were recorded originally in a standard surveyor's field book and later transferred to computer cards for storage and for easy comparison among future surveys. A computer program was written to reduce the field notes and to print the data sheet. Appendix D contains the computer program used and tabular data showing the computer print-outs for each survey. The cross-section profiles are graphically represented in Appendix E.

The profile line direction for each cross-section survey, with only one or two exceptions, was generally from south to north or from west to east. Ground conditions at most survey locations justify elevations only to the nearest 0.02-0.05 foot. Thus the computer print-out data sheets show computed ground elevations rounded to 0.02 foot. Ground conditions must be considered when comparisons are made with future surveys. Station intervals were recorded to the nearest 0.1 foot. The net error of the largest station designations is likely not more than ± 0.5 foot.

The profile lines parallel to the flow at each location were surveyed primarily to establish channel gradient immediately above the cross section. Cross-section locations were chosen such that a relatively straight channel existed for a distance upstream of five times the channel width or greater. The rod readings were recorded to the nearest 0.1 foot, and station intervals were recorded to the nearest foot. The rod readings were made in the lowest part of the channel except where an obvious scour hole existed next to an obstacle. At these locations the rod was placed at the estimated level of the normal channel bottom.

An arbitrary elevation datum was used to determine ground elevations for the profiles at each survey location, and comparisons using absolute elevations among survey locations cannot be made. The tops of the steel stakes used to monument each cross section were designated as temporary bench marks, the elevation of which was arbitrarily taken as 100.00. Ground elevations were calculated relative to this assumed elevation. Future surveys can repeat this procedure, and meaningful comparisons among surveys at each location can be made.

## DETERMINATION OF RUNOFF

Each survey location was examined carefully for evidence of high water marks in the form of stains, floating debris caught in vegetation, washed ground surfaces, etc. High rainful amounts (14-22 inches) were experienced in the park in September, 1978, and water marks from runoff during that period were expected. Significant erosion appeared to have occurred in some locations of the park during that time. Figure 154 shows water marks observed shortly after that storm, and Figure 155 shows some of the erosion that occurred. Rod readings were taken at water marks which were still recognizable at the time of the survey.

Residents on and near the park speak of large runoff occurring in the late 1960's. There was ample evidence in McKittrick Canyon of a larger runoff than the 1978 event. Such evidence can be seen in Figure 155, and even more clearly in Figure 156. One of the cross-section profile lines across McKittrick Canyon (Watershed 6) was within a few feet of a high water marker placed by Roger Reisch, the Chief Park Ranger, during the runoff in the late 1960's. A rod reading was taken at that marker, and at discernible water marks at other survey locations in McKittrick Canyon apparently left by the runoff at that time.

The flowrate in each stream with evidence of high water (runoff) levels was estimated by using the slope-area method using Manning's equation for the velocity component:

$$Q = A \frac{1.49}{n} R^{2/3} S^{1/2}$$

where $Q$ = flowrate in cubic feet per second (cfs)
$A$ = cross-section area of flow in square feet
$n$ = a channel roughness coefficient
$R$ = the hydraulic radius in feet
$S$ = the energy gradient (slope) in feet per foot.

The cross-section area was computed using coordinates from profile data for the depth indicated by the high water marks. The channel roughness coefficients were estimated from on-site observations; their values ranged from 0.040 to 0.050 for the watersheds of the park. The energy gradient (slope) was generally estimated from the channel bottom gradient in the straight section immediately upstream from the cross-section location. The computer program performing the computations and indicating

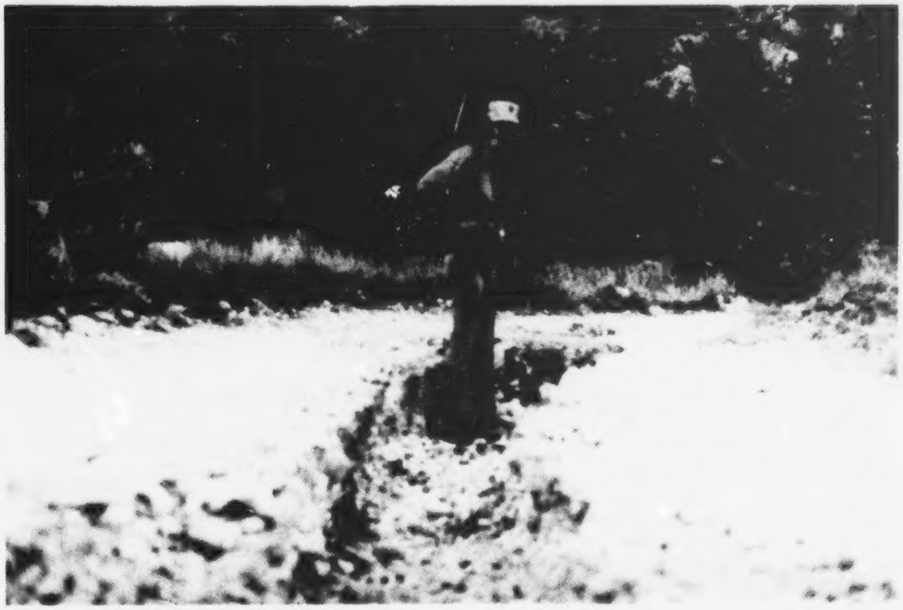

Figure 155. Erosion on trail in McKittrick Canyon.

Figure 156. Flood debris in McKittrick Canyon from a storm prior to September, 1978.

the flowrate is shown in Appendix F. Table 128 presents the calculated peak flowrates/discharges and the drainage areas above each survey location.

The "storm" which occurred in September, 1978, consisted of several intermittent periods of rainfall spanning a period of about 7 days. Most of the rainfall was low intensity, but the long duration resulted in accumulations of 14 to 22 inches. It is likely that relatively high rainfall intensities occurred for short durations at isolated locations in the park at some times during the rainfall period. It is expected that most of the precipitation resulted in runoff after the watersheds had become saturated and significant flowrates should have occurred during the latter part of the storm on all watersheds.

The flowrates reported in Table 128 are lower than expected from a storm which produced so much rainfall suggesting that the watersheds of the park are unique. In particular, the flowrates on Watershed 10A6 on the west side of the park are relatively insignificant. In most channels on this watershed there was no indication of any flow; where there was evidence, indications supported very low flowrates. There was also evidence of diminution of flow down the channel. The flow rate at location 1, Watershed 10A6, the park boundary, was less than that at location 5, and the drainage area at location 1 is approximately 1.5 times greater than the drainage area at location 5. The theory that diminution of flow regularly occurs is substantiated by the observations that the channel size gets smaller as its length increases. This decrease in size can be seen by the comparison of the graphical representations of the cross sections of this watershed shown in Appendix E.

Diminution of flow is also apparent down the channel of Watershed 1 from the values reported in Table 128. The accumulated flowrate past locations 2, 3, and 4 is over 900 cfs, but the flowrate computed at location 1 near the park boundary is only 200 cfs. Diminution of flow likely results from seepage loss in the channel through the porous alluvium and/or cracks and cavern openings.

The remaining watersheds studied were on the east side of the park. There is no observed diminution of flowrates on these watersheds apparent from the values reported in Table 128. This seems to

## TABLE 128. CALCULATED PEAK DISCHARGE FROM WATERSHEDS* (SLOPE-AREA METHOD)

| Watershed | Location | Area in sq. mi. | Flowrate (cfs) 1969 | 1978 |
|---|---|---|---|---|
| 10A6 | 1 | 3.73 | | 50 |
| 10A6 | 2 | 0.97 | | ** |
| 10A6 | 3 | 0.41 | | ** |
| 10A6 | 4 | 0.12 | | ** |
| 10A6 | 5 | 2.39 | | 70 |
| 10A6 | 6 | 2.07 | | ** |
| 1 | 1 | 4.02 | | 200 |
| 1 | 2 | 0.56 | | 200 |
| 1 | 3 | 1.08 | | 20 |
| 1 | 4 | 1.98 | | 700 |
| 1 | 5 | 0.64 | | 600 |
| 6 | 1 | 24.16 | | 2000 |
| 6 | 2 | 14.52 | | 700 |
| 6 | 3 | 7.67 | 7000 | 1000 |
| 6 | 4 | 24.32 | 10000 | 3000 |
| 7 | 1 | 0.41 | | 70 |
| 7 | 2 | 0.36 | | 200 |
| 7 | 3 | 0.44 | | 30 |
| 8B-8D | 1 | 0.29 | | 90 |
| 8B-8D | 2 | 0.15 | | 100 |
| 8B-8D | 3 | 0.10 | | 100 |
| Bowl | 1 | 0.32 | | 500 |
| Bowl | 2 | 0.48 | | 1000 |
| Bowl | 3 | 0.80 | | 50*** |

*Based on observed high water marks
**No water marks observed
***Using the general weir formula

be a characteristic which distinguishes the watersheds draining into the Delaware and Black Rivers from those draining into the Salt Flats Basin. The flowrates on the east side of the park are low, but there is also unexpected variation in flowrates. On Watershed 7 the drainage areas of the sub-watersheds are approximately the same, but the flowrates vary greatly. This suggests again that the watersheds of the park are unique.

## ESTIMATION OF PEAK RUNOFF

Since data was limited and/or more qualitative than quantitative, calculated flowrates are estimates subject to considerable variability. Other methods of estimating runoff were utilized to provide additional predictions of runoff for the selected watersheds.

### RATIONAL METHOD

One of the most commonly accepted and used methods is the rational method which is expressed by the equation:

$$q = CiA$$

where $q$ = peak runoff rate in cubic feet per second

$C$ = runoff coefficient

$i$ = rainfall intensity in inches per hour for the design return period and for a duration equal to the time of concentration of the watershed

$A$ = watershed area in acres.

The runoff coefficient (C) in the rational formula is defined as the ratio of the peak runoff rate to the rainfall intensity (Schwabb, et al., 1966). The runoff coefficient is a function of the soil type, vegetative cover, antecedent moisture conditions, slope, depression storage, intensity of rainfall, and land use.

The determination of rainfall intensity (i) in the rational formula is a function of the time of concentration and varies with the geographical location. In Texas, the Texas Highway Department has developed families of curves which express rainfall intensity as function of the time of concentration for various frequency storms (1970). For Culberson County (in which Guadalupe Mountains National Park is located) the curves are as presented in Figure 157.

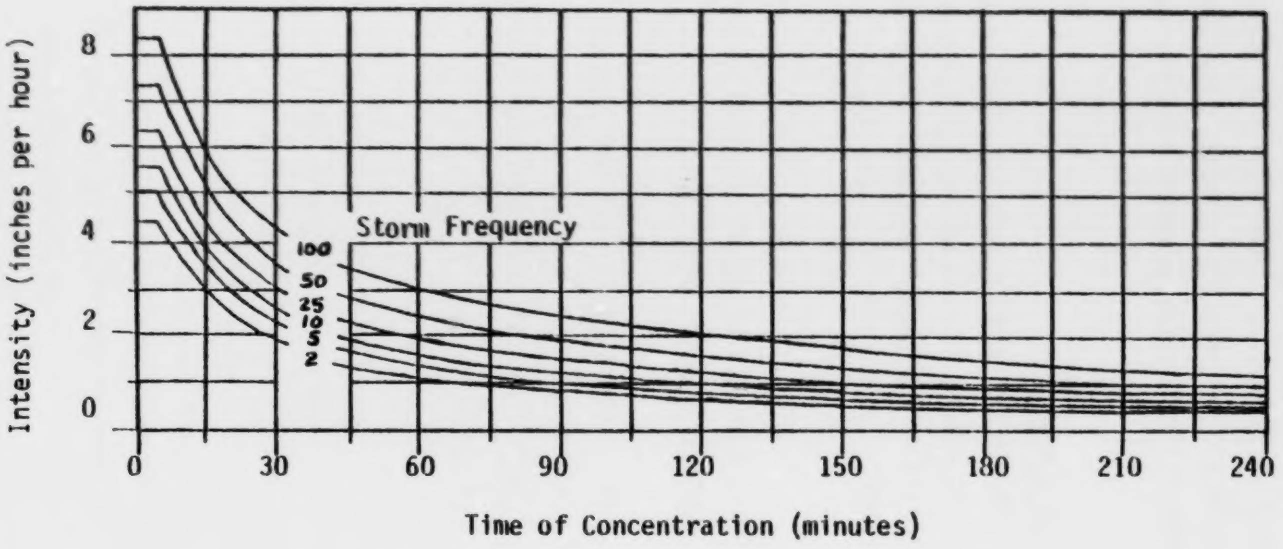

Figure 157. Rainfall intensity curves (Texas Highway Department, 1970.).

The time of concentration of a watershed is the time required for water to flow from the most remote (in time of flow) point of the area to the outlet once the soil has become saturated and minor depressions are filled. It also serves as an indication of the hydrologic response of the watershed. By utilizing the time of concentration, the rational method assumes that all parts of the watershed are contributing simultaneously to the discharge at the outlet, and that the rainfall is uniform throughout the watershed (Schwabb, et al., 1966).

One commonly accepted method of determining the time of concentration was developed by Kirpich (1940) and is expressed as:

$$Tc = 0.0078\, L^{0.77}\, S^{-0.385}$$

where $Tc$ = time of concentration in minutes

$L$ = maximum flow length of feet

$S$ = watershed gradient in feet per foot

The time of concentration for each selected watershed was estimated using the Kirpich method and is reported in Table 129. The reported times of concentration represent a generalized estimate for the total watershed within the park boundary and do not include any subdivision of the watershed to sub-watersheds.

Rainfall intensities utilized in the rational formula were determined from the appropriate rainfall intensity curves for Culberson County, Texas. Rainfall intensities for storm durations equal to the time of concentration for each of the watersheds for storm frequencies of 2, 5, 10, 25, 50 and 100 years are presented in Table 129.

Because of the variability in the selection of the runoff coefficient "C" in the rational formula, peak discharges were calculated for a variety of "C" values ranging from 0.3 to 1.0. This enabled a later comparison with the peak discharges obtained using the Soil Conservation Service method.

The two basic assumptions in the rational method limit its use to generalized runoff computations. As mentioned previously these assumptions are that the rainfall occurs at uniform intensity for a duration equal to the time of concentration, and that the rainfall occurs at a uniform intensity over the entire watershed. The practicality of these assumptions limits the use of the rational formula to small watersheds--generally less than 5 square miles in area.

## TABLE 129. RAINFALL INTENSITIES--RATIONAL METHOD (Inches Per Hour)

| Watershed | Time of Concentration (min) | Storm Frequency (yrs) 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|
| 1 | 57 | 1.1 | 1.4 | 1.6 | 2.0 | 2.5 | 3.1 |
| 6 | 148 | 0.54 | 0.65 | 0.83 | 1.0 | 1.3 | 1.8 |
| 7 | 24 | 2.2 | 2.7 | 3.0 | 3.5 | 4.1 | 4.8 |
| 8B | 20 | 2.5 | 3.0 | 3.4 | 3.8 | 4.5 | 5.2 |
| 8D | 47 | 1.2 | 1.6 | 1.8 | 2.2 | 2.7 | 3.4 |
| 10A6 | 43 | 1.4 | 1.7 | 2.0 | 2.4 | 2.9 | 3.5 |
| Bowl | 13 | 3.3 | 3.8 | 4.2 | 4.6 | 5.5 | 6.3 |

Tables 130-136 present the results of each series of determinations using various "C" values for each watershed and for storm frequencies ranging from 2 to 100 years. Based on the narrative descriptions of parameters associated with the various "C" values contained in the Texas Highway Department Hydraulic Manual (1970) C = 0.8 would appear to be an appropriate selection for the watersheds being studied.

## SOIL CONSERVATION METHOD

Another method of determining the rate of runoff is the Soil Conservation Service method (1978). The Soil Conservation Service method can be used to develop composite hydrographs at any point within a watershed by dividing the watershed into subareas and then determining the time of concentration for each subarea and the travel time through each reach. This method is especially applicable for complex watersheds up to approximately 20 square miles.

The Soil Conservation Service (SCS) method utilizes the soil type, land use, drainage area, and time of concentration as in the rational method. The SCS method, however, uses the 24-hour rainfall total for different frequency storms. These rainfall totals are based on historical records and for this study were taken from Technical Paper # 40--a United States Weather Bureau Publication (1963). Twenty-four hour precipitation totals for appropriate return periods are shown in Table 137.

TABLE 137. 24-HOUR RAINFALL--CULBERSON COUNTY, TEXAS

| | Return Period (yrs) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 5 | 10 | 25 | 50 | 100 |
| Rainfall Amount (inches) | 1.5 | 2.0 | 2.6 | 3.1 | 3.6 | 4.1 | 4.8 |

Utilization of the SCS method requires the determination of a runoff curve number for each of the watersheds based on the soil type and land use. Soils are classified into one of four hydrologic soil groups according to soil texture. For example, clay soils have the highest runoff potential and are classified into hydrologic soil group D, while sandy soils with high infiltration rates have a low runoff potential and

TABLE 130. PEAK DISCHARGE WS-1 RATIONAL METHOD (Cubic Feet Per Second)

| | Storm Return Period (yrs) | | | | | |
|---|---|---|---|---|---|---|
| "C" | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.3 | 1500 | 1900 | 2200 | 2800 | 3500 | 4300 |
| 0.4 | 2000 | 2600 | 3000 | 3700 | 4600 | 5700 |
| 0.5 | 2500 | 3200 | 3700 | 4600 | 5800 | 7200 |
| 0.6 | 3100 | 3900 | 4400 | 5600 | 6900 | 8600 |
| 0.7 | 3600 | 4500 | 5200 | 6500 | 8100 | 10000 |
| 0.8 | 4100 | 5200 | 5900 | 7400 | 9300 | 11000 |
| 0.9 | 4600 | 5800 | 6700 | 8300 | 10000 | 13000 |
| 1.0 | 5100 | 6500 | 7400 | 9300 | 12000 | 14000 |

TABLE 131. PEAK DISCHARGE WS-6 RATIONAL METHOD (Cubic Feet Per Second)

| | Storm Return Period (yrs) | | | | | |
|---|---|---|---|---|---|---|
| "C" | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.3 | 2600 | 3200 | 4000 | 5000 | 6300 | 8800 |
| 0.4 | 3500 | 4200 | 5400 | 6600 | 8400 | 12000 |
| 0.5 | 4400 | 5300 | 6700 | 8300 | 11000 | 15000 |
| 0.6 | 5200 | 6300 | 8100 | 9900 | 13000 | 18000 |
| 0.7 | 6100 | 7400 | 9400 | 12000 | 15000 | 20000 |
| 0.8 | 7000 | 8400 | 11000 | 13000 | 17000 | 23000 |
| 0.9 | 7900 | 9500 | 12000 | 15000 | 19000 | 26000 |
| 1.0 | 8800 | 11000 | 13000 | 17000 | 21000 | 29000 |

## TABLE 132. PEAK DISCHARGE WS-7 RATIONAL METHOD (Cubic Feet Per Second)

| | Storm Return Period (yrs) | | | | | |
|---|---|---|---|---|---|---|
| "C" | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.3 | 710 | 860 | 970 | 1100 | 1300 | 1500 |
| 0.4 | 950 | 1100 | 1300 | 1500 | 1800 | 2100 |
| 0.5 | 1200 | 1400 | 1600 | 1900 | 2200 | 2600 |
| 0.6 | 1400 | 1700 | 1900 | 2300 | 2600 | 3100 |
| 0.7 | 1700 | 2000 | 2300 | 2600 | 3100 | 3600 |
| 0.8 | 1900 | 2300 | 2600 | 3000 | 3500 | 4100 |
| 0.9 | 2100 | 2600 | 2900 | 3400 | 4000 | 4600 |
| 1.0 | 2400 | 2800 | 3200 | 3800 | 4400 | 5200 |

## TABLE 133. PEAK DISCHARGE WS-8B RATIONAL METHOD (Cubic Feet Per Second)

| | Storm Return Period (yrs) | | | | | |
|---|---|---|---|---|---|---|
| "C" | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.3 | 72 | 86 | 98 | 110 | 130 | 150 |
| 0.4 | 96 | 120 | 130 | 150 | 170 | 200 |
| 0.5 | 120 | 140 | 160 | 180 | 220 | 250 |
| 0.6 | 140 | 170 | 200 | 220 | 260 | 300 |
| 0.7 | 170 | 200 | 230 | 260 | 300 | 350 |
| 0.8 | 190 | 230 | 260 | 290 | 350 | 400 |
| 0.9 | 220 | 260 | 290 | 330 | 390 | 440 |
| 1.0 | 240 | 290 | 330 | 360 | 430 | 490 |

TABLE 134. PEAK DISCHARGE WS-8D RATIONAL METHOD
(Cubic Feet Per Second)

| | Storm Return Period (yrs) | | | | | |
|---|---|---|---|---|---|---|
| "C" | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.3 | 130 | 170 | 190 | 230 | 280 | 350 |
| 0.4 | 170 | 220 | 250 | 300 | 370 | 470 |
| 0.5 | 220 | 280 | 310 | 380 | 470 | 590 |
| 0.6 | 260 | 330 | 370 | 460 | 560 | 710 |
| 0.7 | 300 | 390 | 440 | 530 | 650 | 820 |
| 0.8 | 350 | 440 | 500 | 610 | 750 | 940 |
| 0.9 | 390 | 500 | 560 | 680 | 840 | 1100 |
| 1.0 | 430 | 550 | 620 | 760 | 930 | 1200 |

TABLE 135. PEAK DISCHARGE WS-10A6 RATIONAL METHOD
(Cubic Feet Per Second)

| | Storm Return Period (yrs) | | | | | |
|---|---|---|---|---|---|---|
| "C" | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.3 | 1000 | 1300 | 1500 | 1800 | 2200 | 2600 |
| 0.4 | 1300 | 1700 | 2000 | 2300 | 2900 | 3500 |
| 0.5 | 1700 | 2100 | 2500 | 2900 | 3700 | 4400 |
| 0.6 | 2000 | 2500 | 3000 | 3500 | 4400 | 5200 |
| 0.7 | 2400 | 3000 | 3500 | 4100 | 5100 | 6100 |
| 0.8 | 2700 | 3400 | 4000 | 4700 | 5900 | 7000 |
| 0.9 | 3000 | 3800 | 4500 | 5300 | 6600 | 7800 |
| 1.0 | 3400 | 4200 | 5000 | 5900 | 7300 | 8700 |

TABLE 136. PEAK DISCHARGE WS-BOWL RATIONAL METHOD
(Cubic Feet Per Second)

| | Storm Return Period (yrs) | | | | | |
|---|---|---|---|---|---|---|
| "C" | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.3 | 510 | 580 | 640 | 710 | 840 | 960 |
| 0.4 | 680 | 780 | 850 | 950 | 1100 | 1300 |
| 0.5 | 840 | 970 | 1100 | 1200 | 1400 | 1600 |
| 0.6 | 1000 | 1200 | 1300 | 1400 | 1700 | 1900 |
| 0.7 | 1200 | 1400 | 1500 | 1700 | 2000 | 2200 |
| 0.8 | 1400 | 1600 | 1700 | 1900 | 2300 | 2600 |
| 0.9 | 1500 | 1800 | 1900 | 2100 | 2500 | 2900 |
| 1.0 | 1700 | 1900 | 2100 | 2400 | 2800 | 3200 |

are classified as hydrologic soil group A. Land use classifications range from cultivated land to pasture or range land to wood or forest land, and runoff curve numbers are given for any combination of land use and hydrologic soil group (Soil Conservation Service, 1978). These curve numbers were developed based on experimental watersheds with known soil types and land uses and are presented in Table 138.

TABLE 138. RUNOFF CURVE NUMBERS FOR SELECTED LAND USES AND HYDROLOGIC SOIL GROUPS

| | Hydrologic Soil Group | | | |
|---|---|---|---|---|
| Land Use Description | A | B | C | D |
| Pasture or range land: poor condition | 68 | 79 | 86 | 86 |
| Pasture or range land: good condition | 39 | 61 | 74 | 80 |
| Meadow: good condition | 30 | 58 | 71 | 78 |
| Wood or forest land: thin stand, poor cover, no mulch | 45 | 66 | 77 | 83 |
| Wood or forest land: good cover | 25 | 55 | 70 | 77 |

After the runoff curve number is established, the depth of runoff is found for selected curve numbers and rainfall amounts using tables based upon the equation:

$$Q = \frac{(P-0.2S)^2}{P+0.8S}$$

where $Q$ = actual direct runoff in inches

$P$ = total storm rainfall in inches

$S$ = potential abstraction in inches

The potential abstraction S is related to the soil and cover conditions of the watershed and represents the maximum amount of moisture retained by the particular soil and vegetative cover. The runoff curve number (CN) is also related to those conditions and is related to the potential abstraction S by:

$$S = \frac{1000}{CN} - 10$$

The complexity of the watersheds in the study area necessitated the use of a tabular method of flood routing. The basic information was obtained from the SCS publication "Tabular Method of Flood Routing--24-Hour Type II Storm Distribution" (1978). Tabular discharges are included for a range of time of concentration values from 0.1 to 12 hours and valley times from 0 to 30 hours. The discharges are expressed in terms of cubic feet per second per square mile per inch of runoff. The tables were developed by hydrographs for a one square mile of drainage area for a range of times of concentration and routing them through stream reaches with a range of travel times. Tabular flood routing facilitates summing individual hydrographs of sub-areas to develop a composite hydrograph for a particular point of interest.

The SCS method of estimating runoff rates is also applicable to the determination of the total volume of runoff from the watershed. The actual direct runoff (Q) for a particular rainfall event and a runoff curve number may be used to calculate the volume of runoff by:

$$V = \frac{(Q)\,A}{12}$$

where $V$ = volume of runoff in acre feet

$Q$ = actual direct runoff in inches

$A$ = area of watershed in acres

Utilization of the SCS method of determining peak discharges required the delineation of sub-areas within each main watershed. Sub-areas within each major watershed were delineated on United States Geological Survey 7-1/2 minute quadrangle maps (1:24,000) and are shown in Appendix G. The delineations were based primarily on locations of significant channel intersections. The sub-areas are not identical to the sub-watersheds delineated for the profile surveys, but in some instances they are nearly the same. The size of each of the sub-areas was measured by the use of a fixed arm compensating polar planimeter. Three measurements were made for each area and an average was determined. The average reading, in square inches was then converted to square miles using the following formula:

$$A = \frac{a\,(91.827)}{640}$$

where $A$ = size of sub-area in square miles a = basin area in square inches on the map

91.827 = number of acres per square inch on the map at a scale of 1:24,000

640 = number of acres per square mile

Channel lengths through each sub-area as well as the furthest hydrologic distance within each sub-area were obtained with a map measure wheel from United States Geological Survey 7-1/2 minute quadrangle maps. These lengths and their corresponding elevation differences were utilized in the computation of the travel time through each sub-area and the time of concentration for each sub-area, respectively. Care was taken to divide channel lengths into segments of similar slope as observed visually on the maps. Elevation differences within each segment were obtained by interpolating between contours on the map and subtracting the resulting lower elevation from the upper elevation. Kirpich's formula, discussed previously, was then utilized to obtain estimates of the travel time and time of concentration for each sub-area.

A composite runoff curve number was determined for each major watershed, based primarily on the land system classification developed by Fuller (1976). The various land system groups were determined based on vegetation, geologic materials, and slope. The composite runoff curve numbers are presented in Table 139. Watershed characteristics used to determine the runoff curve number are presented in Appendix H.

TABLE 139. COMPOSITE RUNOFF CURVE NUMBERS

| Watershed | Runoff Curve Number |
|---|---|
| 1 | 72 |
| 6 | 73 |
| 7 | 68 |
| 8B | 68 |
| 8D | 81 |
| 10A6 | 70 |

Unit hydrographs, which indicate the rate of discharge and periods of runoff, were developed for each major watershed. These unit hydrographs are shown in Figures 158 through 163. Also shown in each Figure are the expected number of inches of runoff for different frequency storms, the anticipated peak discharge, and the runoff volume. The development of the unit hydrograph for Watershed 1 is presented in Appendix I.

## COMPARISON OF METHODS

A comparison of the two methods of estimating peak discharges (rational and SCS) from the watersheds reveals significant variations in results. While a "C" value of 0.8 in the rational method would be expected to be applicable to most of the watersheds because of the steep terrain, peak discharges computed with a "C" value of 0.3 more closely correspond witn results obtained with the SCS method for most of the watersheds. Exceptions are Watershed 6, in which a "C" value of 0.4 appears to be best, and Watershed 8D, in which a "C" value of 0.6 appears to be best.

Comparison of flowrates from the 1969 storm in Watershed 6 derived using the slope-area method with the results of the rational and SCS methods reveals relatively* close correlation. The 1969 storm is generally considered to have been a 100-year storm, and peak discharge determined by the slope-area method is estimated as 10,000 cfs. The rational method (for C = 0.4) and the SCS method both estimate 10,000 cfs peak discharge for a recurrance interval of 100 years.

Analysis of the recorded climatological data in regard to peak discharge required the determination of those rainfall events which had a duration greater than or equal to the time of concentration of the watershed. This data was compiled from the event recorder charts for each of the six watersheds of interest and is presented in Table 140. A closer examination of recorded rainfall intensities reveals that no intensities were recorded which would correspond to even a two-year frequency storm in the rational method. Several 24-hour storms were recorded, however, with rainfall amounts in excess of the historical one-year storm, as presented in Table 141. In addition,

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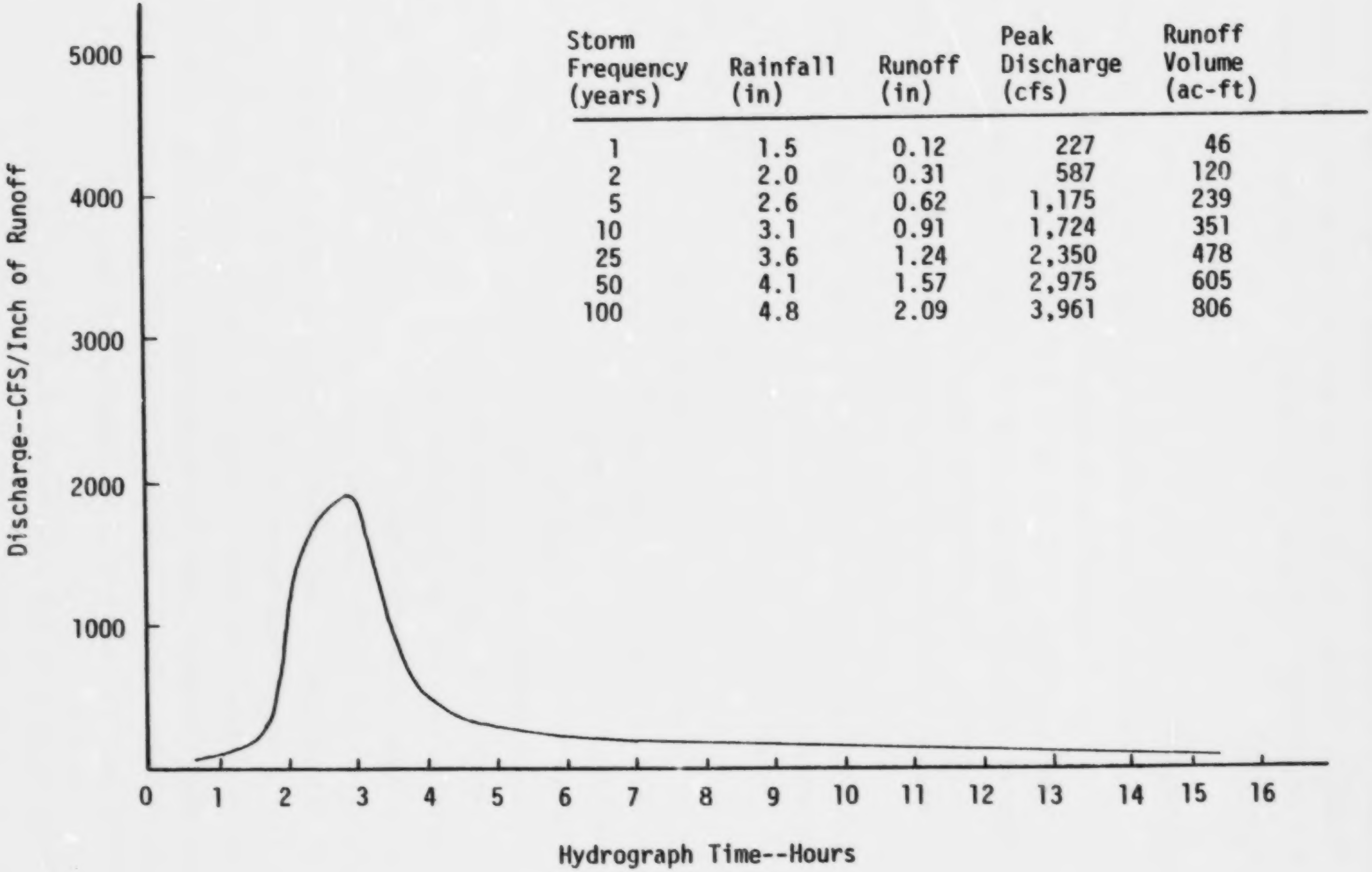
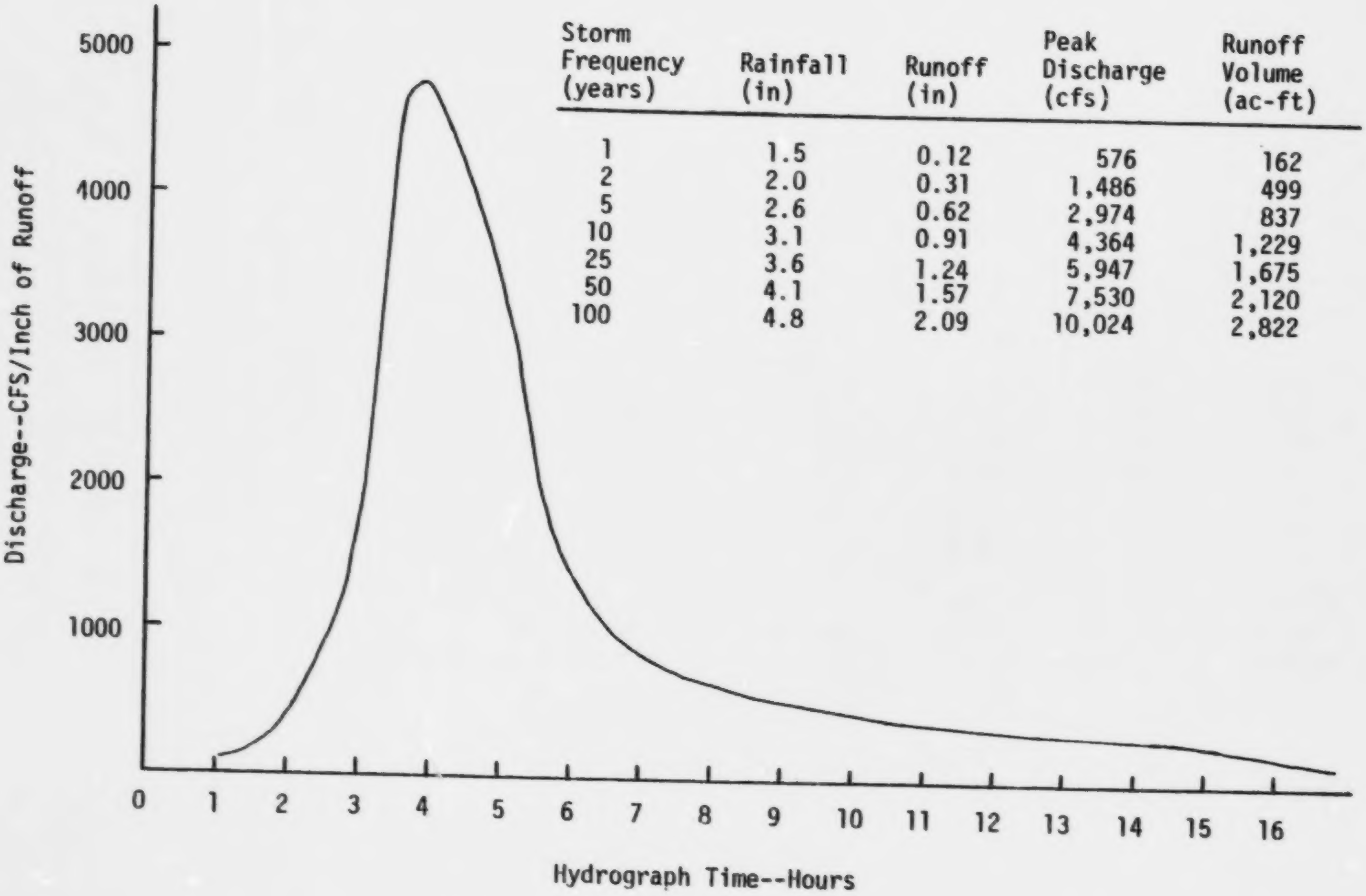
*Only values with one significant figure were compared.



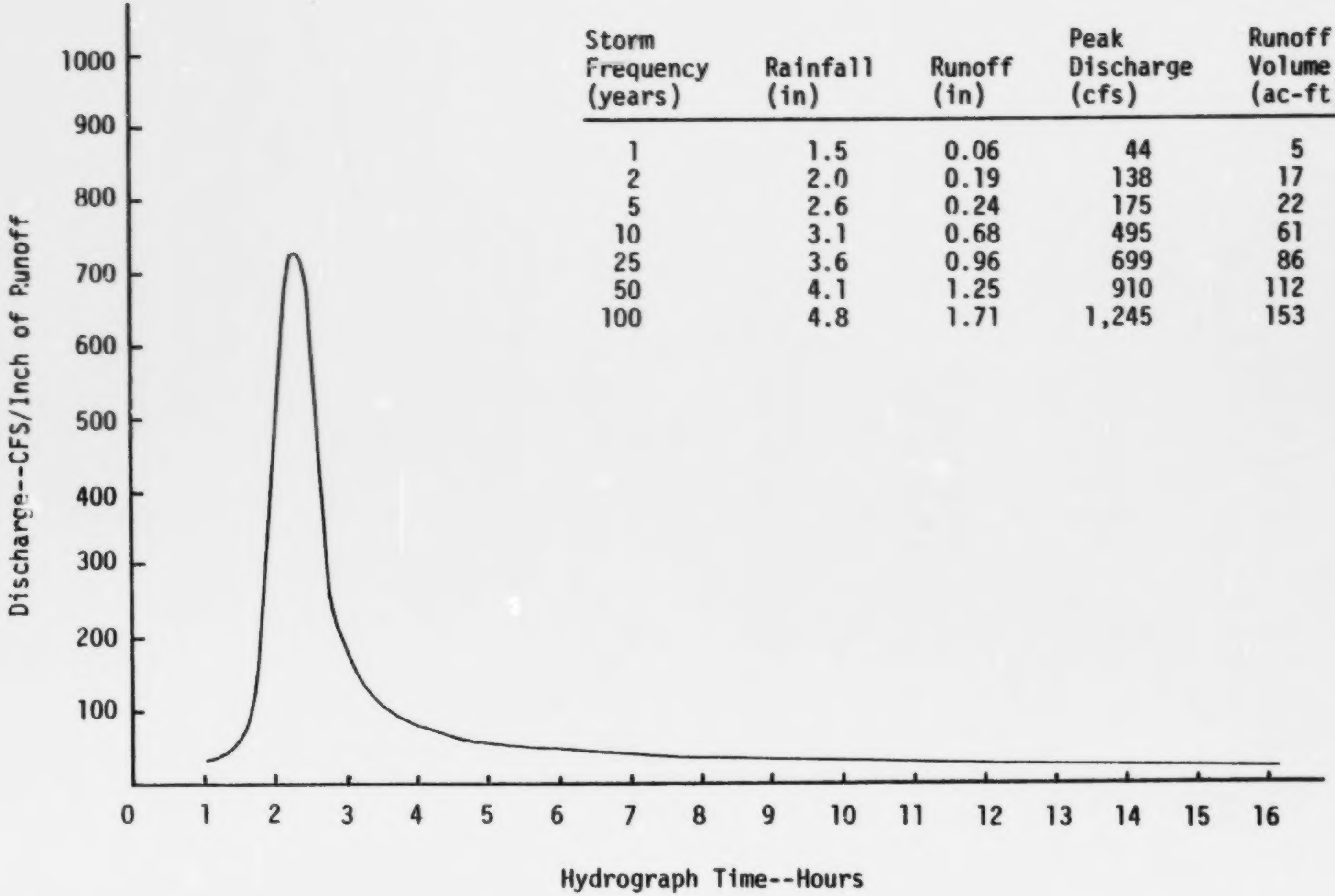
| Storm Frequency (years) | Rainfall (in) | Runoff (in) | Peak Discharge (cfs) | Runoff Volume (ac-ft) |
|---|---|---|---|---|
| 1 | 1.5 | 0.12 | 227 | 46 |
| 2 | 2.0 | 0.31 | 587 | 120 |
| 5 | 2.6 | 0.62 | 1,175 | 239 |
| 10 | 3.1 | 0.91 | 1,724 | 351 |
| 25 | 3.6 | 1.24 | 2,350 | 478 |
| 50 | 4.1 | 1.57 | 2,975 | 605 |
| 100 | 4.8 | 2.09 | 3,961 | 806 |

Figure 158. Unit hydrograph--Watershed 1.



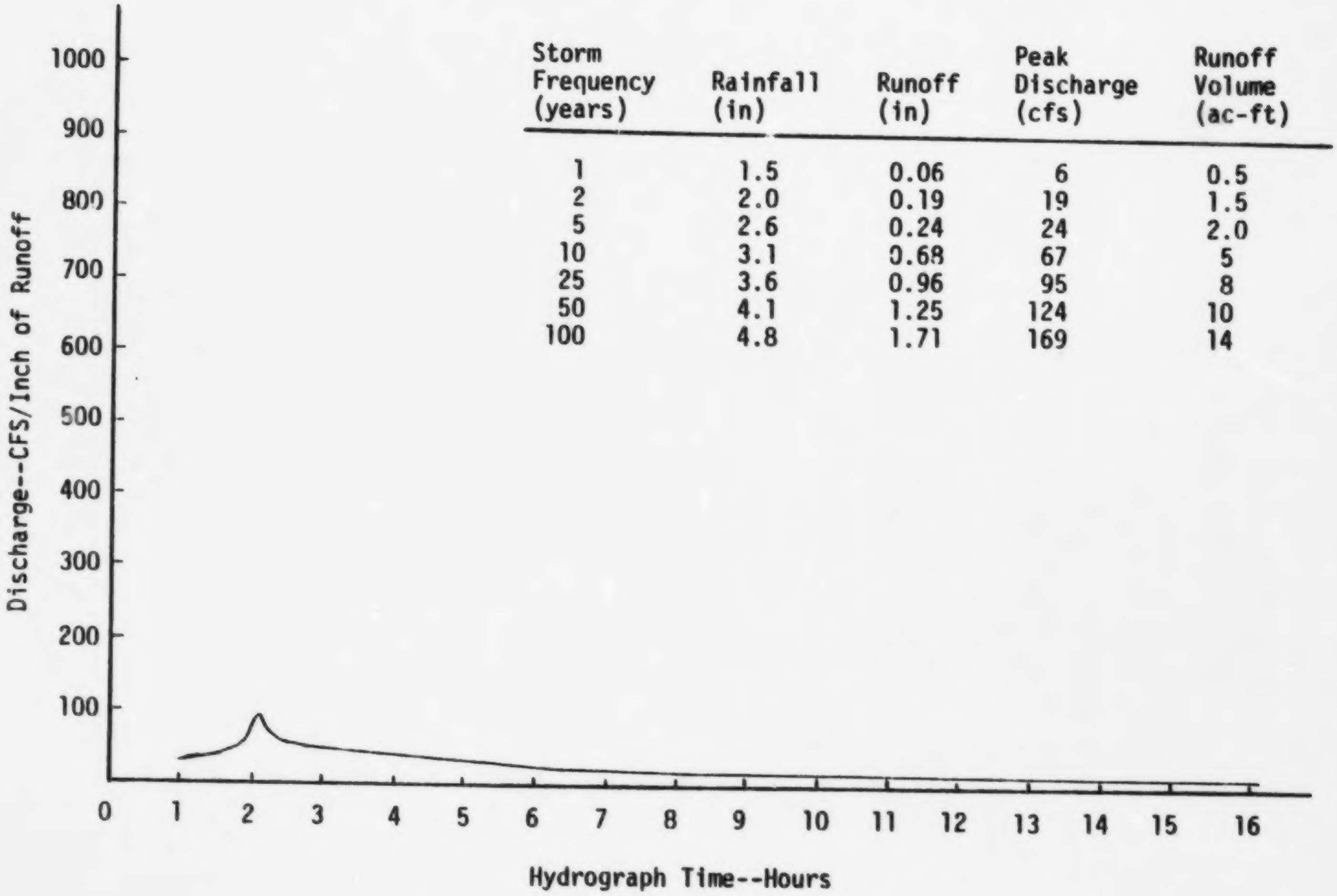
| Storm Frequency (years) | Rainfall (in) | Runoff (in) | Peak Discharge (cfs) | Runoff Volume (ac-ft) |
|---|---|---|---|---|
| 1 | 1.5 | 0.12 | 576 | 162 |
| 2 | 2.0 | 0.31 | 1,486 | 499 |
| 5 | 2.6 | 0.62 | 2,974 | 837 |
| 10 | 3.1 | 0.91 | 4,364 | 1,229 |
| 25 | 3.6 | 1.24 | 5,947 | 1,675 |
| 50 | 4.1 | 1.57 | 7,530 | 2,120 |
| 100 | 4.8 | 2.09 | 10,024 | 2,822 |

Figure 159. Unit hydrograph--Watershed 6.



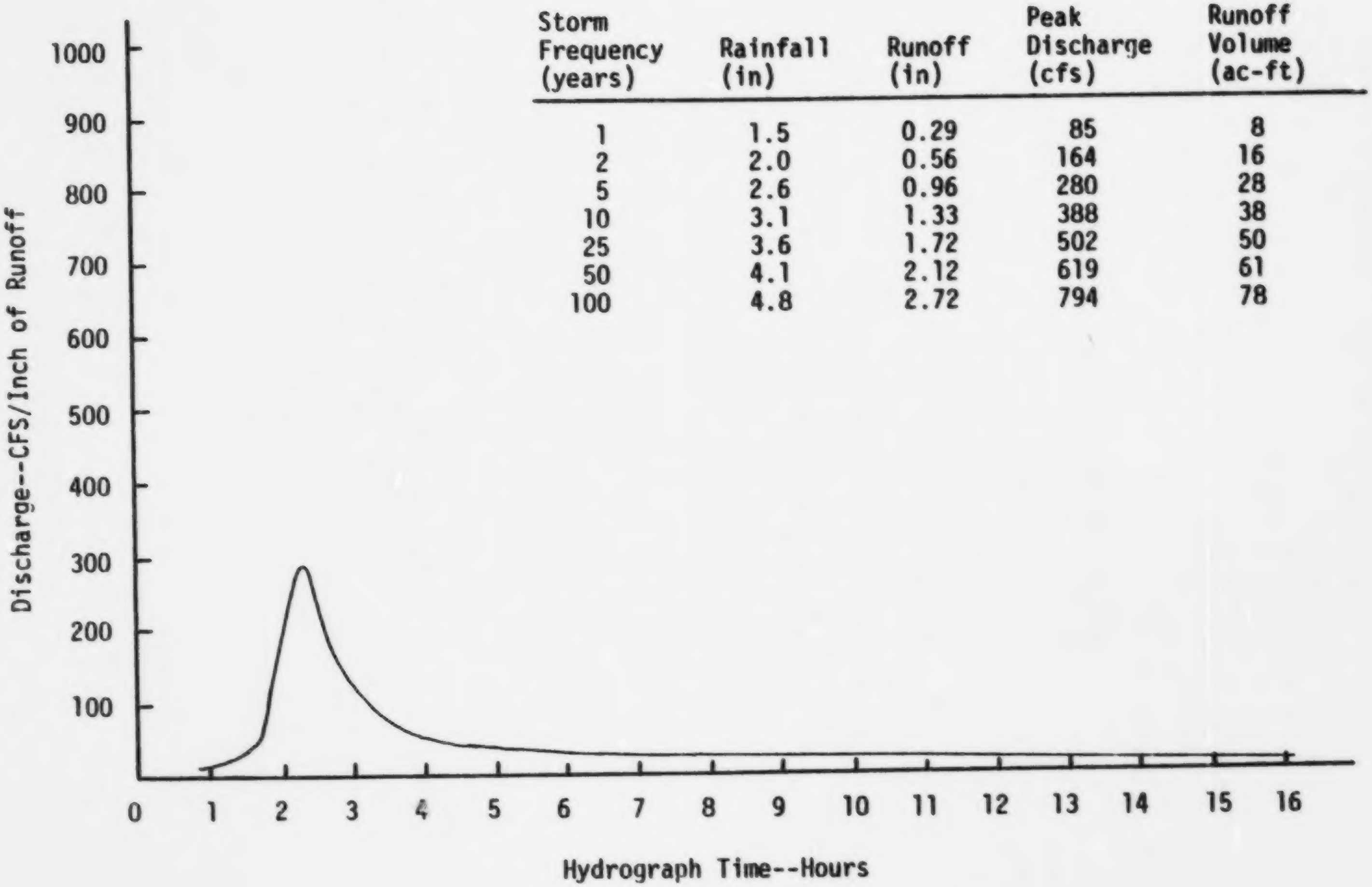
| Storm Frequency (years) | Rainfall (in) | Runoff (in) | Peak Discharge (cfs) | Runoff Volume (ac-ft) |
|---|---|---|---|---|
| 1 | 1.5 | 0.06 | 44 | 5 |
| 2 | 2.0 | 0.19 | 138 | 17 |
| 5 | 2.6 | 0.24 | 175 | 22 |
| 10 | 3.1 | 0.68 | 495 | 61 |
| 25 | 3.6 | 0.96 | 699 | 86 |
| 50 | 4.1 | 1.25 | 910 | 112 |
| 100 | 4.8 | 1.71 | 1,245 | 153 |

Figure 160. Unit hydrograph--Watershed 7.



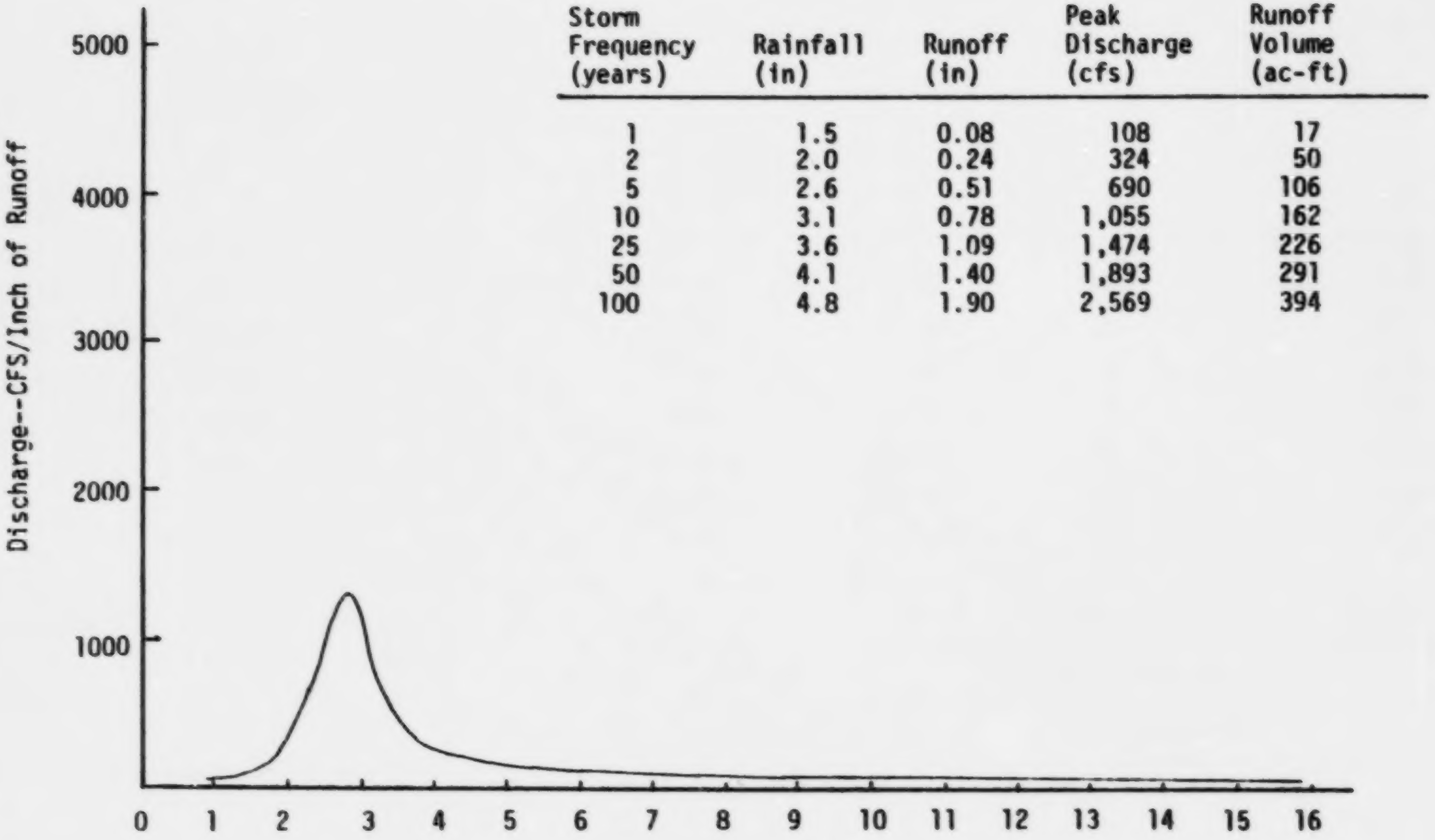
| Storm Frequency (years) | Rainfall (in) | Runoff (in) | Peak Discharge (cfs) | Runoff Volume (ac-ft) |
|---|---|---|---|---|
| 1 | 1.5 | 0.06 | 6 | 0.5 |
| 2 | 2.0 | 0.19 | 19 | 1.5 |
| 5 | 2.6 | 0.24 | 24 | 2.0 |
| 10 | 3.1 | 0.68 | 67 | 5 |
| 25 | 3.6 | 0.96 | 95 | 8 |
| 50 | 4.1 | 1.25 | 124 | 10 |
| 100 | 4.8 | 1.71 | 169 | 14 |

Figure 161. Unit hydrograph--Watershed 8B.



| Storm Frequency (years) | Rainfall (in) | Runoff (in) | Peak Discharge (cfs) | Runoff Volume (ac-ft) |
|---|---|---|---|---|
| 1 | 1.5 | 0.29 | 85 | 8 |
| 2 | 2.0 | 0.56 | 164 | 16 |
| 5 | 2.6 | 0.96 | 280 | 28 |
| 10 | 3.1 | 1.33 | 388 | 38 |
| 25 | 3.6 | 1.72 | 502 | 50 |
| 50 | 4.1 | 2.12 | 619 | 61 |
| 100 | 4.8 | 2.72 | 794 | 78 |

Figure 162. Unit hydrograph--Watershed 8D.



| Storm Frequency (years) | Rainfall (in) | Runoff (in) | Peak Discharge (cfs) | Runoff Volume (ac-ft) |
|---|---|---|---|---|
| 1 | 1.5 | 0.08 | 108 | 17 |
| 2 | 2.0 | 0.24 | 324 | 50 |
| 5 | 2.6 | 0.51 | 690 | 106 |
| 10 | 3.1 | 0.78 | 1,055 | 162 |
| 25 | 3.6 | 1.09 | 1,474 | 226 |
| 50 | 4.1 | 1.40 | 1,893 | 291 |
| 100 | 4.8 | 1.90 | 2,569 | 394 |

Figure 163. Unit hydrograph--Watershed 10A6.

TABLE 140. SUMMARIZATION OF PRECIPITATION EVENTS WITH DURATIONS EQUAL OR GREATER THAN TIME OF CONCENTRATION

| | | | Intensity | | Duration | |
|---|---|---|---|---|---|---|
| Watershed | Weather Station | Number of Events ≥ Tc | Max. Recorded Intensity (in/hr) | Duration (hrs) | Max. Recorded Duration (hrs) | Intensity (in/hr) |
| 1 | 1 | 40 | 0.43 | 7.00 | 27 | 0.11 |
| 6 | 6 | 18 | 0.39 | 19.25 | 21 | 0.36 |
| 6 | Bowl | 26 | 0.22 | 6.00 | 18 | 0.09 |
| 7 | 8B-8D | 44 | 0.69 | 1.50 | 9 | 0.02 |
| 8B | 8B-8D | 68 | 1.80 | 0.50 | 9 | 0.02 |
| 8D | 8B-8D | 44 | 0.69 | 1.50 | 9 | 0.02 |
| 10A6 | 10A6 | 38 | 0.48 | 2.00 | 12 | 0.15 |

TABLE 141. RAINFALL EVENTS EXCEEDING HISTORICAL ONE-YEAR STORM

| | Weather Station | | | | |
|---|---|---|---|---|---|
| Date | 1 | 6 | Bowl | 8B-8D | 10A6 |
| 10/3/77 | | | 1.57 | | |
| 10/4/77 | | | | 1.50 | |
| 5/19/78 | | 1.51 | | | |
| 9/3/78 | | | | 1.78 | |
| 9/23/78 | 2.50 | 2.49 | * | | 1.76 |
| 9/24/78 | 5.50 | 4.33 | * | 2.24 | 2.80 |
| 9/25/78 | 3.59 | 7.68 | * | 6.02 | |
| 9/26/78 | | | * | 1.48 | |

*Event recorder malfunctioned during this time period. Storage gauge accumulation was in excess of 20.0 inches for an eight-day period.

TABLE 142. UNIT PEAK DISCHARGES--SOIL CONSERVATION SERVICE METHOD

| | | Discharge (cfs) | |
|---|---|---|---|
| Watershed | Area (sq. mi.) | Per Inch Runoff | Per Inch Runoff Per Square Mile |
| 1 | 7.23 | 1,895 | 262 |
| 6 | 25.32 | 4,796 | 189 |
| 7 | 1.58 | 728 | 433 |
| 8B | 0.15 | 99 | 660 |
| 8D | 0.54 | 292 | 541 |
| 10A6 | 3.39 | 1,352 | 348 |

several of these events were in excess of the 100-year 24-hour storm. This would indicate that, for the park area, rainfall intensities used in the rational method would need to be revised downward, while maintaining traditionally high runoff "C" values.

Examination of the unit hydrographs shows peak discharges occurring between 2 and 4 hours after the start of the rainfall events. The consistency with which the peak occurs in each watershed is due primarily to the use of the 24-hour Type II storm distribution. The Type II distribution represents regions in which the high rates of runoff from small watersheds are usually generated from summer thunderstorms. The distribution of rainfall within the 24-hour period is based on historical average ratios of accumulated rainfall to total rainfall. The lack of significant runoff prior to the peak discharge is also due to interception, surface detention storage, and initial abstraction by the soil surface.

The steep slopes of the rising limb of each unit hydrograph indicates the degree of severity with which the peak discharges may be expected to occur. This is especially evident in Watershed 6, which also has the highest peak discharge. Table 142 summarizes the unit quantities of runoff expected from each watershed as calculated by the SCS method.

The hydrologic characteristics of the selected watersheds are presented in Table 143. Parameters of particular interest in regard to the unit discharges are the compactness coefficient and circulatory ratio. These parameters express the degree of compactness or degree of circularity of the watershed. Theoretically the closer the values are to unity, the greater the likelihood will be that precipitation will be quickly concentrated in the main channel, resulting in peak flows. The values of Table 142 do not indicate such a relationship, however, primarily due to the extremely large variation in size among the watersheds. As expected, the larger watersheds yield the highest peak flows, but the smaller watersheds characteristically yield the greatest rates of flow per unit area.

## TABLE 143. HYDROLOGIC CHARACTERISTICS OF SELECTED WATERSHEDS

| Watershed | Area mi$^2$ | Perimeter mi. | Compactness Coefficient | Circulatory Ratio | Max. Elevation ft. | Min. Elevation ft. | Channel Length mi. | Mean Channel Slope ft./mi. |
|---|---|---|---|---|---|---|---|---|
| 1 | 7.23 | 11.48 | 1.20 | 0.69 | 7,780 | 5,940 | 5.15 | 357 |
| 6 | 25.32 | 29.68 | 1.66 | 0.36 | 8,480 | 4,900 | 14.69 | 244 |
| 7 | 1.68 | 5.85 | 1.27 | 0.62 | 6,985 | 4,900 | 2.59 | 815 |
| 8B | 0.15 | 2.46 | 1.79 | 0.39 | 5,570 | 5,300 | 1.10 | 245 |
| 8D | 0.54 | 5.70 | 2.19 | 0.21 | 5,495 | 5,025 | 2.78 | 169 |
| 10A6 | 3.89 | 11.64 | 1.66 | 0.36 | 7,680 | 3,705 | 5.21 | 763 |

## EROSION TRANSECTS

Erosion transects (detailed ground profiles) were measured at various locations within each watershed selected for intensive investigation. Each transect location was monumented so it could be measured again to determine the amounts and rates of soil erosion/deposition. Transect locations included frequently used trails/roads, infrequently used trails/roads, hillsides receiving no traffic, and drainageways of small watersheds. Erosion resulting from raindrop splash, runoff, and/or foot traffic and wheel traffic can be determined from subsequent measurements at the same locations. Transect locations were numbered within each watershed and are shown in Figures 146-150 for each watershed.

The monuments used to mark each transect location were steel stakes driven into the ground at each end of a transect line. After the transect was measured, many of the stakes were hidden from view by a rock cairn built around them. Several photographs/slides were taken at the transect locations to document their location and present appearance. Figure 164 is representative of the pictorial record obtained. A complete set of photographic records and associated field notes is filed with the Park Headquarters and at Texas Tech University for reference purposes.

The equipment for measuring each transect included a steel cable (approximately 3 mm in diameter), turnbuckles, hooks, and a scale. After the steel stakes were driven into the ground, each was notched with a file to provide a constant reference position. The cable was attached to a hook at one end and a turnbuckle at the other end. The hook and the free end of the turnbuckle were placed at the notches in the stakes, and the turnbuckle was drawn together until there was no observable sag in the cable, and the cable felt very tight. At most locations the stakes were placed and notched to provide a level cable. Where this was not possible, the rise/fall along the cable was noted. Thirty-four station positions were marked on the cable at 6 inch (15 cm) intervals beginning approximately 3 feet (.9 m) from the hook. At each station the vertical distance from the top of the cable to the ground was measured to the nearest 1/8 inch (3 mm). Figures 165 and 166 show the cable stretched and ready for measurements at two different transect locations.

Figure 164. Rock cairns around erosion transect monument. Watershed 7, location 4.

Figure 165. Erosion transect at location 5 in the Bowl across Bush Mountain trail.

Figure 166. Cable stretched for making erosion transect at location 2 of Watershed 10A6.

The data were converted to SI units and were transferred to computer cards for storage and for easy comparison among future measurements. A computer program was written to compute ground elevations. For these computations, the elevation of the cable at the first station was arbitrarily taken to be 100.00 cm. The computer program and the ground elevations computed* for each location are shown in Appendix J.

A second computer program was written to compute differences in ground elevation observed at subsequent measurements to help assess the amount and rate of erosion/deposition occurring at each location. This computer program also is shown in Appendix J.

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*The output format of the computer program was altered to allow the presentation of these values in a more compact format for this report.

# CHAPTER X LANDSCAPE UNIT ANALYSIS

Regionalization, the attempt to divide the surface of the earth into areas which are internally homogeneous and distinct from adjacent areas, has been going on at least since Aristotle divided the known world into torrid, temperate and frigid zones. The study of regions is the bête noire of many geographers and arguments range from the contention that every point on earth is unique to that of the absolute existence of the region as a concrete unit. Even when regionalization is accepted as a reasonable method for studying areal relationships, there are endless arguments about the location of boundaries. As E.C. Semple (1911) describes the problem: "Nature abhors fixed boundary lines and sudden transitions; all her forces combine against them. Everywhere she keeps her boundaries melting, wavering, advancing, retreating."

In spite of the debates on the existence of regions and the location of boundaries, there is a general recognition that if we are to use our lands in the best ways possible, it is necessary that we make some attempt to order the tremendous natural variety that surrounds us. Even Hartshorne, a major proponent of the concept that every point on earth is unique, writes that:

> . . . geography seeks to organize knowledge of the world into interconnected systems, in order that any particular fragment of knowledge may be related to all others that bear upon it. . . . The problem of dividing the world, or any part of it, into subdivisions in which to focus the study of areas is the most difficult problem of organization in

> regional geography. It is a task that involves a complete division of the world in a logical system, or systems, of division and subdivision, down to ultimately the approximately homogeneous units of areas. Difficult though the task may be, the principles of completeness and organization demand that geography seek the best possible solution. (Hartshorne, 1939)

We seek to order knowledge, to classify it, in order to understand and evaluate large quantities of data. Therefore, it is necessary to accept some level of variability such that the variability of factors within an area is less than the variability of factors between adjacent areas. In addition no element or factor of an area exists in isolation; it is related to and influenced by other factors to varying degrees. Because factors are interrelated, some degree of homogeniety can be expected; some generalization is possible.

In managing land for whatever purpose, the requirements include economy and practicality. Vast amounts of point data are useless if the object of study is to form some rational basis for making decisions about managing land. It is neither economical nor practical to manage hundreds of tiny pieces of land in differing ways. Thus we must accept some level of generalization; and we must be prepared to define those levels of generalization in order to make reasonably accurate statements about land areas, their potentials and liabilities.

As a consequence of the diversity of the park and the need to protect the resources as well as provide for the enjoyment of visitors, it is necessary for the Park Service to identify and assess as quickly as possible the land areas which will require different management practices. If this is to be done economically, a technique must be used which obviates a great deal of field work since the mountains are extremely rugged and access is difficult. To be practical, areas must be homogeneous enough to respond predictably to a given management practice, yet large enough to prevent differing management practices from coming into conflict.

## PREVIOUS WORK

The difficulties encountered in the development of techniques and specific details necessary to implement this concept of regionalization or land classification are readily attested to by the vast and interesting body of literature on the subject.

According to Mabbutt (1968), there are three main approaches to land classification. The first, the genetic approach, "attempts to arrive at distinctive land units by repeated subdivision on the basis of causal environmental factors." The subdivisions must be linked by their genetic history. The problem with this approach arises because different factors change at different rates and over space, thus areas within a given physiographic region may be "closely related to the subjacent geological formations, but unrelated to each other or to the compound whole." (Linton, 1951).

A second approach has been designated as the landscape concept. Initially developed through the work of Bourne (1931) and Unstead (1933), this method defines small areas and combines them into larger areas on the basis of the interrelation of many factors, one or more of which may be dominant at a given time or place. The main problem with this approach is that with successively higher orders, generalization increases and accuracy is reduced. Secondly, the approach is qualitative; the ranges of the factors involved are not described definitively and may vary within and among several studies (Mabbutt, 1968).

The third approach, the parametric approach, attempts to quantitatively classify and divide land "on the basis of selected attribute values." New technologies have provided means of identifying attributes which heretofore had to be inferred, and of handling large amounts of data quickly and inexpensively. Problems with the parametric approach include "the choice of attributes and the delimitation of attribute classes; the variance of attributes in space and time, and the translation into terms of land of the areas of occurrence and association of selected parameters." (Mabbutt, 1968).

Regardless of the type of approach, all methods must ultimately deal with and, in some manner, define levels within the classification scheme. Major contributions in this area have been made by investigators in Australia, Great Britain, and the Soviet Union with several recent contributions by United States scientists.

In the late 1940's, Australia was one of several countries which recognized a need to inventory and evaluate as quickly as possible its resource capabilities. Huge areas of the continent were virtually unknown and unmapped, yet there was neither time nor money to be expended on single purpose, detailed investigations. As a consequence the Division of Land Use Research of the Commonwealth Scientific and Industrial Research Organization (CSIRO) chose to use and expand upon the landscape concept by defining and then identifying land units and land systems on aerial photographs (Christian and Stewart, 1953, 1968).

They defined the land system as "an area or group of areas, throughout which there [was] a recurring pattern of topography, soils and vegetation." The recurring pattern was caused by land units each defined as having a distinct combination of topography, soil and vegetation. A further subdivision, the site, was defined as being "for all practical purposes, uniform throughout its extent in landform, soil and vegetation." (Christian and Stewart, 1968).

Christian and Stewart (1968) primarily delineated boundaries along a "discernible geological or geomorphogenic feature or process." It should be noted that the Australians assigned equal importance to "all significant factors, land form, soil, vegetation, drainage, climate and impact of man." Although not explicitly stated, it is implied that a boundary line may occur due to any one or a combination of factors. Extensive use of aerial photography was made both in the lab and in the field to initially define boundaries which were refined if necessary based on ground truth* derived from sample transects in the final field work.

The researchers state categorically "that the [land system] concept can be used at a variety of scales," and that at one scale a landform, such as floodplain, may be a land unit, and at a larger scale, a land system (Christian and Stewart, 1968). Thus the areas can vary tremendously in size and complexity. For example, mapping scales in the land surveys of CSIRO ranged from 1:250,000 to 1:1,000,000; survey areas from 8,240 to 373,000 square kilometers; land systems from 10 to 17,800 square kilometers; land units from 1.5 to 7,250 square kilometers; and photo scales from 1:16,000 to 1:85,000. Survey areas were also not always covered with the same scale of photography.

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*Ground truth is a collection of data obtained through actual field reconnaissance.

> In other words the terms land system and land unit give no indication of the size of the area in question or the detail of mapping. Their flexibility is further shown by the fact that one land system mapped by Christian and Stewart (1953) at 8 miles to the inch (1:506,880) was mapped by Speck et al. (1961) as 20 land systems at 4 miles to the inch (1:253,440). (Story, et al., 1976)

Often management policy decisions, mapping scales and the amount and quality of available data largely determine the degree of internal homogeneity implied by the application of the terms land system, land unit and site within a particular study area.

For example, if the State of Texas were the entire study area, the high plains area of West Texas could be a land system, the dissected portions along the Canadian River would be land units and within these, the banks and floodplains of the river would be sites. Alternatively, if only the high plains were being studied, one land system might be the upland areas containing playa lakes, another the Canadian River; the playa lakes, the banks and floodplains would be some of the land units and the sites would be smaller areas represented by various soil and vegetation groups.

A second major contribution to land classification comes from Great Britain primarily as a result of military requirements to classify terrain for engineering purposes. However, as it was realized that applications would be mostly for civilian purposes, the aim of the studies turned toward a more general classification which could have wider application. "What was wanted was the potential for predicting soil and terrain or land conditions over large areas of relatively undeveloped countries where information [was] sparse." (Webster and Beckett, 1970).

The land facet, the fundamental unit of this classification consisted of a usually simple landform "on a particular rock or superficial deposit," and with a uniform or simple variation of a soil and water regime. The researchers recognized that these areas tended to recur in a more or less regular pattern which defined the land system.

A land system then was recognized when a different group of land facets was encountered or "where the patterns of relationships between the land facets differed." In the event that land facets were not homogeneous enough for the intended purposes, they could be subdivided into land elements (Webster and Beckett, 1970). The land element was defined as being equivalent to the site of Bourne (1931), viz., "an area which, for all practical purposes, provides throughout its extent similar conditions as to climate, physiography, geology, soil and edaphic factors in general."

One of the purposes of the studies was to evaluate the use of aerial photography as a tool for identifying and delineating land system and land facet boundaries. All boundaries were conditional until such time as field sampling could be done to verify them (Webster and Beckett, 1970). It was not stated by the researchers whether or not the units would change if the size of the study area were increased or decreased.

The photography and mapping scales used were: 1:10,000 or larger for land elements; 1:10,000 to 1:50,000 or slightly smaller for land facets; and 1:250,000 to 1:1,000,000 for land systems.

The Soviet Union has made a third major contribution to land classification as a result of its efforts to rapidly evaluate extensive areas of land as part of a national plan to modernize and expand agriculture.

V.V. Dokuchayev is considered to be the father of landscape science in the Soviet Union, not because he named it, but because he was the first to stress the need to "'study the one, whole and indivisible nature and not its fragments.'" (Isachenko, 1973). In consequence, Soviet researchers realized that, in order to comprehend and manage land areas, they must study them as integrated complexes of many factors. L.S. Berg, a disciple of Dokuchayev, first coined the term landscape science and in his publications developed two interpretations of landscape: one, a very broad view, "groups together all the similar and homogeneous sections of the earth's surface regardless of the location." (Isachenko, 1973). That is, all areas which exhibited comparable associations of features would be grouped together as representing similar environments regardless of their location on the earth's surface, e.g., all deserts would be considered as one landscape, all forests, plains, etc. In contradistinction to that view, Berg also developed the conception of a landscape being a unique, non-recurring entity, viz., that each land area on earth was absolutely distinct from all others because of the particular associations of factors and the genetic history of each landscape had no equivalent elsewhere. Each desert was unique as was each upland or plain. The latter view was more thoroughly developed by S.V. Kalesnik who showed that though a landscape was morphologically heterogeneous, it was an integral and unique territory because of its genetic history. N.S. Solntsev, at the Moscow State University, carried out extensive landscape surveys which appeared to confirm that view. The result of their work and the "reconstruction of geographic theory on the foundation of dialectical materialism, contributed greatly to the subsequent development of landscape science." (Isachenko, 1973). Thus due to past experience (including political philosophy) Isachenko (1973) states that most geographers in the Soviet Union "treat as basic the so-called regional concept of landscape according to which every landscape constitutes, first of all, a concrete (individual) territorial unit, and secondly a fairly complex geographic entity consisting as a rule of many elementary physical geographic units."

The variations of the definitions of the term landscape in Soviet literature are numerous, but most exhibit similar characteristics. Solntsev (1962) used the definition that a landscape was:

> . . . a genetically uniform natural territorial complex characterized by a single geological base, a single type of relief and climate, and consisting of a set of primary and secondary urochishcha specific to that landscape dynamically associated and regularly patterned in space.

The next two subdivisions in order of size were the urochishcha (singular, urochishche) and the facies (singular, facia). Vinogradov, et al. (1962) defined these as follows:

> [The facia] . . . the smallest (elementary) physical geographic unit having homogeneous site and habitat conditions and a single biocoenosis. . . . The urochishche . . . an association of facies related to the individual convexities and concavities in medium-sized relief forms or to level interfluve areas with a homogeneous substratum and united by a common direction of drainage, of the transfer of solid material and the migration of chemical elements.

Solntsev (1962) cited three conditions for differentiating independent landscapes:

> (1) the terrain on which the landscape is established must have a uniform geological base;*
> (2) following the formation of this base the subsequent developmental history of the landscape throughout its area must be identical . . . :
> (3) the climate must be identical over the entire landscape and seasonal changes must remain uniform throughout, (that is, within a landscape we can have only a variation in local climate in individual urochishcha and in microclimates in facies).

The landscape, according to Soviet scientists, is considered to be the fundamental areal unit because of its indivisibility which is based on the unique occurrence of zonal and azonal factors. Zonal factors occur due to the "regular variation in all geographic components and landscapes with latitude" (e.g., climate, vegetation, soils, etc.). Since zones do not always follow lines of latitude and are frequently discontinuous, either zones must be discarded or the reasons for the variations determined. Zones are a result of solar energy, but the earth also has its own internal energy. The conclusion is that it is tectonic movements which have caused the surficial differentiation and it is these phenomena which constitute "the clearest manifestations of azonal differentiation." Thus Isachenko argues that because a combination of zonal and azonal factors is unique in any area, therefore this constitutes an indivisible unit, the landscape (Isachenko, 1973).

For support he cites Solntsev (1962) who notes that facies and urochishche are not unique because they can recur, they can change (landscapes are considered to change so slowly as to be permanent for all intents and purposes), and they are not necessarily characteristic of the landscape to which they belong.

There is some disagreement among Soviet geographers regarding the uniformity of a facia or urochishche and whether or not the landscape should be the unique fundamental unit. Yefremov (1961) notes that subdivisions like facies and urochishcha are just as complex and no more fundamental than a landscape. This idea is supported by Prokayev (1962) who believes that (1) there has been as yet no real definition as to what constitutes one soil type, one biocenosis, etc.; (2) there is only a degree of homogeneity within a facies; and (3) the

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*"It is not necessary for the geological base of a landscape to consist of a single rock type." As long as the genetic history is uniform, a landscape could include intrusive outcrops, various sedimentary rocks on a folded base, etc. (Isachenko, 1973).

> . . . lack of coincidence or the incomplete coincidence of boundaries of particular complexes (soils, vegetation, etc.) within the facies is explained not only by the fact that the various particular disciplines have not yet achieved a uniform approach to the identification of elementary complexes but by the fact that relationships and interactions between natural components are not functional but correlative (D.L. Armand, 1952); the rates of development of individual components are also not identical.

The Soviets, too, recognize that landscape boundaries are not defined by a single factor, but are due to the interaction of various factors. One factor may tend to dominate (and often this is a geologic or geomorphologic expression), but for the boundary to be very distinct "all the components must alter sharply and simultaneously." (Isachenko, 1973). Though for the most part landscapes are considered permanent, it is realized that they do change over time due to external, e.g., climatic, and internal, e.g., vegetation, changes. "Owing to the non-uniform development of individual components, landscape boundaries are somewhat diffuse." (Isachenko, 1973).

Though Soviet researchers mention that use of aerial photography is made, they consistently avoid any detailed descriptions of methodology. They do, however, give map scales at which various units are mapped. Kalesnik (1961): individual landscapes--1,200,000 to 1:300,000; urochishcha--1,100,000; urochishcha and groups of facies (not individual facies)--1:25,000. Vinogradov, et al. (1962) vary this somewhat: landscapes--1:1,000,000 or smaller; mestnosti (associations or complexes of urochishcha)--up to 1:1,000,000; urochishcha--up to 1:100,000; facies--1:10,000 or larger.

As an example of the types of land areas that would correspond to the terminology, the State of Texas will again serve as an illustration. If the entire state were the study area, one landscape would be the high plains; the Canadian River and its tributaries would be the urochishcha and the facies would be the banks and floodplains. In contrast to the Australians, these areas would retain their classifications, even if the study area were only the high plains themselves.

Researchers in the United States have made the fourth important contribution to land classification. I. Bowman and N.M. Fenneman initiated physiographic land classification in the United States. They based their systems on the ideas of W.M. Davis who had originated a scheme for classifying landforms, but they carried their ideas beyond those of Davis. Bowman began the process of dividing the United States "into physiographic provinces, each of which had similar stages of development." Fenneman refined the classifications and further subdivided the provinces into sections and districts (Heath, 1956).

Human geographers took exception to these classifications as being much too large for the study of areal relations in human occupance as well as being too broad in their descriptions. Bowman himself realized the need to study land in its relation to humans. Based on his work in the Andes of South America, he developed "topographic types" which were, on the whole, landforms as they related to cultural activities and because of this work, he never again drew a physiographic boundary (Heath, 1956).

In 1922 the Michigan Land Survey was begun and Carl Sauer, in an effort to avoid the production of another soil survey map, succeeded in having the study oriented toward land types. In the 1941 report, Veatch defined the "natural land types" as:

> . . . a natural subdivision based on the intrinsic nature of the soil; the nature of the soil association, a uniformity or complexity of distinct types; the topography; the natural drainage; and the native vegetation. A map of natural land types would be subject to no greater change and would have no less permanent value than a soil map or a geological map.

Although many western geographers denounced (and still deny) the existence of "natural areas," nevertheless the Michigan Land Survey had introduced the concept of a land area made up of a complex of interrelated and relatively homogeneous factors into the literature. The importance of this way of thinking is that the landscape is considered as a whole and, though a few of the characteristics of the landscape may be of greater interest than others, they cannot be studied or understood in isolation (Mabbutt, 1968).

Marschner (1959), a leading proponent of the use of the landscape concept, used aerial photography of the United States for the purpose of identifying land practices based on complex photo images, "but he was reluctant to apply his idea in a systematic and diagnostic manner." (Peplies and Keuper, 1975). Austin (1965) used the technique to produce Major Land Resource Regions and Major Land Resource Areas of the United States and this effort was followed by Baker and Dill (1970a, 1970b, 1971a, 1971b, 1971c) who produced a five-volume atlas using photographic images to delineate the major agricultural areas and sub-areas of the United States. The concept of complex photographic images was used by MacPhail in a study conducted in Chile, where he coined the term "photomorphic area" and defined it as a composite "of the geometry of the fields and fence lines, the pattern of drainage, and the tone ranges relating to land use, rock outcrop, soil moisture and vegetation." (MacPhail, 1971). A greater emphasis was placed on cultural activities than in the work of the Soviets or Australians, although they, too, recognized that human impacts do affect boundary delineations especially in the lower order subdivisions. As MacPhail pointed out "the principal descriptive and identifying information consists of recognizing the surficial and photographic features with respect to their continuity, uniformity, outstanding tonal qualities, and characteristics of apparent form." (MacPhail, 1971).

In the Chilean study, the major photomorphic areas were delineated according to the "major north-south physical zones"; the next lower photomorphic sub-areas were broadly based on major vegetation, e.g., forests; landforms, e.g., dunes; or [illegible]ltural effects, e.g., cultivated land. MacPhail used aerial photographic mosaics of 1:100,000 some at 1:50,000 and photomaps at 1:20,000 to map the photomorphic areas. Aerial photographs at 1:20,000 were used for field work (MacPhail, 1971). Nichol, a student of MacPhail, used the photomorphic concept in a study of Boulder County, Colorado. The purpose was to identify and compare different land types "according to their constraints and values for agricultural and urban uses." She used color infrared photography at a scale of 1:100,000 (Nichol, 1975).

The concept of the photomorphic region has since been used by Peplies and Wilson (1970), Peplies and Flynn (1972), Flynn (1974), and Keuper, et al. (1977). All of these studies were done using satellite imagery at small scales (1:500,000 or less) of the southeastern United States. Most of this work involved the use of such techniques as microdensitometer readings and Fourier-transforms to recognize ranges of tone and texture signatures which could be used to identify homogeneous areas on the imagery.

In order to compare the works of the various researchers, the terminologies must first be equated where possible (see Table 144). The definitions of land system (Christian and Stewart, 1968; Webster and Beckett, 1970), landscape (Isachenko, 1973; Solntsev, 1962) and photomorphic area (MacPhail, 1971) all appear to be roughly equivalent. Although Christian and Stewart (1968) equate land system with urochishche, the editor of Isachenko's book, J.S. Massey, states that urochishche is more nearly equivalent to the Australians' land unit. The definitions cited previously tend to confirm Massey's opinion. According to the definitions, then, land units (Christian and Stewart, 1968), land facets (Webster and Beckett, 1970) urochishche (Vinogradov, et al., 1962) and the smaller photomorphic areas (MacPhail, 1961) can be considered comparable. The smallest units are perhaps the closest in terms of definition by all the authors; site (Christian and Stewart, 1968); land element (Webster and Beckett, 1970); facia (Vinogradov, et al., 1962). MacPhail did not identify an equivalent element.

The important points of the methodologies to be compared are (1) whether or not the various researchers analyzed the homogeneity of their land areas, (2) what techniques they used to do so, and (3) how the boundaries are tested.

Christian and Stewart (1953, 1968) used aerial photography to initially delineate land system boundaries occurring along a definite geologic or geomorphogenic feature and land units were the repetitive landforms occurring therein. Field work was carried out only in those areas showing the greatest potential for the objectives of their studies. The personnel involved represented several different disciplines and they worked together in the field and the lab in order to integrate their diverse knowledge. This was considered essential since a land system or land unit represented a complex of interacting factors including soil, vegetation, geology and climate. Sampling was done by transects within

TABLE 144. EQUIVALENT TERMINOLOGY

| Christian and Stewart | Webster and Beckett | Solntsev, Isachenko | MacPhail |
|---|---|---|---|
| land system | land system | landscape | major photomorphic area |
| land unit | land facet | urochishche | photomorphic sub-area |
| site | land element | facia | (no equivalent element) |

units and across boundary lines. These data were then used to more fully describe the landforms of the areas and to define boundary lines. Homogeneity, per se, was not tested except as it was represented by recurring patterns and substantiated by field descriptions. No attempt was made to verify entire boundaries as this would have conflicted with the study objectives of speed and economy.

Though the purpose of Webster and Beckett (1970) was to seek information for undeveloped countries, they conducted their first tests in England. Land systems and land facets were delineated from aerial photographs and random samples were made which covered approximately one-fourth of the study area and included representatives of all land facets which had been identified. In order to test the homogeneity of the land facets, they recorded soil profiles, particle distribution, soil water tension and soil strength. The last were tested by analysis of variance to indicate the degree of homogeneity within a given terrain class as well as interclass correlation. They found that the correlation of soil water tension and soil strength was high enough to allow for some generalizations about the properties within a class and that there was enough difference in these properties between classes to indicate that the land areas were different. However, when soil chemical properties were tested, the variances were too large to allow generalizations within classes and separation between classes was poor.

Although several scientists in the Soviet Union mentioned that aerial photographs were used for landscape identification and delineation of boundaries (Isachenko, 1961, 1973; Kalesnik, 1961; Vinogradov, et al., 1962; Vinogradov, 1968), discussion of test methodologies is singularly absent. One exception is Gerenchuk, et al. (1970) who have tried to develop physical parameters which would allow a more quantitative systematic approach to classification of landscapes. The complexity of a landscape was established based on size and number of subdivisions. A landscape having many different subdivisions of a variety of sizes would be highly complex and vice versa. Dominance and insignificance of subdivisions were also based on size and number. That is, for subdivisions to be dominant there must be many of the same order and they should be of a large geographical size relative to all others of the same order. Insignificant ones should be small and occur infrequently.

The four basic approaches used to study complexity were: matrices, histograms; a coefficient of complexity test; and "entropic measures of diversity." The matrices were set up with landscapes in the left column and the different types of urochishcha across the top. Presence or absence of a particular kind of urochishcha was indicated by 1 or 0 respectively. The summations by landscape would indicate levels of complexity. For example, a landscape with ten different urochishcha would be more complex than one with only two or three urochishcha. Histograms were developed for each landscape with individual bars representing each urochishcha; the height of the bars represented the areal extent of each urochishcha. Landscapes could then be described by the variation in height of the bars, e.g., "pronounced multipeaked . . . pronounced stepped," etc. The coefficient of complexity test required the use of complicated cartometric measurements which were not described. "The complexity of structure of landscapes [was] directly proportional to the number of morphologic elements and inversely proportional to their mean size"; i.e., the bigger the number obtained from the equation, the more complex the landscape. The technique called "entropic measures of diversity" used a ratio of the area of a subdivision to the total area of the landscape. The interpretation given the ratio was that it represented "the probability of occurrence of the particular morphologic element." (Gerenchuk, et al., 1970).

The researchers also conducted a test for homogeneity using the mutual disposition or contiguity of various elements. In the test the elements were arranged in the same order in rows and columns to form a matrix. Where two elements touched, a '1' was used and where they did not, a '0' was placed. The number of neighbors was obtained by adding along rows or columns and the variance of the series of numbers indicated whether or not elements had roughly the same number of neighbors. The higher the variance, the greater the degree of contrast within a landscape (Gerenchuk, et al., 1970).

As to verifying boundaries delineated from aerial photographs, no methodology is described. Apparently a great deal of field work is carried on, but no mention is made of any sampling techniques or other comparative methods.

A.D. Armand (1973) has also attempted to develop a more formal methodology for testing the boundaries and homogeneity of regions. He used an "information-gradient" method involving the collection of data along transects which crossed landscape boundaries. The selected parameters were measured along the transects and then subjected to mathematical analysis. If there was a minimum gain of new information, this was assumed to represent a regional core. That is, if the parameters and their measurements did not change very much, then this indicated the presence of a homogeneous area. Where a maximum amount of new information was gained, it was assumed that a boundary between two landscapes or urochishcha occurred. However, as the author pointed out, the technique has a drawback "that is inherent in all methods involving transition from profile to area." To some extent this could be overcome by increasing the number of profiles, but this would entail a great deal of field work.

Work in the United States has ranged from subjective verifications based on field work (MacPhail, 1971; Nichol, 1975) to highly qualified and mechanized analysis of imagery (Peplies and Wilson, 1970; Peplies and Flynn, 1972; Flynn, 1974; Keuper, et al., 1977). MacPhail, in his work in Chile, and Nichol, in her study in Colorado, both indicated that photomorphic boundaries were subjectively verified during field work by noting what changes in the cultural or physical landscape corresponded to aerial photographic boundaries (MacPhail, 1971; Nichol, 1975). Homogeneity in the Chilean study was determined by extensive sampling of cultural features as they related to the different land areas (MacPhail, 1971). In verifying the delineated land types in Colorado, Nichol (1975) substantiated these through field observations, interviews and census information. Boundaries were refined by using thematic maps (e.g., geology, vegetation, soil engineering and agricultural capability, etc.), but "in each case, information from the thematic maps was related subjectively to the areas provided by the photomorphic mapping." (Nichol, 1975).

The studies by Peplies and Wilson (1970), Peplies and Flynn (1972), Flynn (1974) and Keuper, et al. (1977) have all used satellite photography or scanner images at small scales (1:500,000 or less). Peplies and Wilson (1970) did not conduct any tests for homogeneity or boundary delineation, though census data and some field work were used for subjective comparisons. Homogeneity was analyzed by Peplies and Flynn (1972) and Flynn (1974), but only in relation to four subjective categories of tone exhibited on the imagery. Where tonal patterns changed, boundaries were delineated. Little field work was conducted. The study by Keuper, et al. (1977) followed up on the previous studies using two approaches. First they attempted to refine the tonal categories through additional use of the microdensitometer and to add texture as another diagnostic characteristic of homogeneity and boundary definition. For the latter, they employed Fourier-transform techniques, but had little success. As a second means of defining photomorphic regions, the researchers collected census data and attempted to predict the appearances of photomorphic images. Some success was achieved, but this was limited largely to the prediction of boundaries between urban and rural areas and between crop land and woodland or forest.

In general, the following comparisons can be made. The Australians have used sampling to test the validity of boundaries, but complete verification was not done. Field work was also done to more fully describe various entities within land systems or land units, but homogeneity was tested only in terms of the recurrence of patterns on aerial photographs. The British were more quantitative, but they examined features which were unobservable on aerial photographs and their results were inconclusive. The Soviets have looked at the complexity of landscapes and their subdivisions in terms of the number and sizes of the units. Homogeneity tests were made on the basis of either the numbers of neighbors of a given unit or on the minimum gain of information along a transect. Boundaries, as delineated on aerial photographs, are assumed to be correct; the only test mentioned is based on the occurrence of a maximum amount of information recorded at one point. Researchers in the United States have studied boundaries and homogeneity either subjectively or through intensive analysis of imagery only.

## DATA COLLECTION

The purpose of this aspect of the research program was to differentiate relatively homogeneous areas within Guadalupe Mountains National

Park in order to gain useful information in recreation management. The specific objectives are: (1) to thoroughly test the boundaries delineated from aerial photographs using complete ground truth data on slope, vegetation and geology; (2) to compare all land areas with each other to determine their degree of uniqueness; and (3) to examine the homogeneity of the delineated areas in terms of the patterns of the aforementioned factors.

The most intensive research using the land system or landscape concept has dealt with lowlands or relatively level surfaces. Little work has been done on mountains because they are not the foci for agricultural or urban development and they are frequently difficult of access. Mountains usually exhibit great variance in such factors as slope, elevation, geology and vegetation. That is, the factors often do not exist as continuous expanses; rather, they occur in small areas and are widely dispersed. This diverse character is exhibited in Guadalupe Mountains National Park where the land rises abruptly from nearly level desert to a forested plateau.

After examining the aerial photographic delineations and the available ground truth data, it was decided that the variety and arrangement of the biophysical factors within the park as well as management needs precluded the use of any of the land classification terms described in the literature.

First, if the park were to be classified into land systems, there would probably be only two, the mountains and the plains (or perhaps three, since the plains can be divided into two distinct elevation levels). This would follow the designation that a land system boundary usually occurs along a major geologic or geomorphologic change and the genesis of each is different. The land systems would be much too broad to convey any real information for the type of management required. Second, land units would be too small and uneconomical for management; further, the effort needed to identify them would probably not produce any essential information that could not be as readily derived from the sites. Third, sites were readily obtainable from existing ground truth. Fourth, because the variety of vegetation, geology and slope is so great in the Park and also because many areas may require very intensive management, it is necessary to choose a classification unit level which is large enough to be economically managed, yet small enough to be relatively homogeneous.

The aerial photographic delineations did not solely depict either major geologic or geomorphogenic changes (land system boundaries) or single landforms (land units), but they did reveal repetitive patterns. As a result, it was decided that the delineations represented an intermediate classification between land system and land unit and the repetitive patterns were the sites. The intermediate classification term was designated as the landscape unit. A landscape unit is defined as an area exhibiting a photographic image of repetitive pattern, tone and texture, the boundaries of which do not necessarily coincide with major geologic or geomorphologic divisions or specific landforms, but which are determined by the occurrence of groups of repetitive sites.

There are five major steps to achieve the objectives set forth: (1) delineate landscape unit boundaries on aerial photography; (2) determine the kinds and quantities of various physical and biological factors in each landscape unit from ground truth; (3) test the aerial photographic delineations with ground truth in order to verify the boundaries; (4) test for any similarities among landscape units; (5) test the landscape units for internal homogeneity.

The landscape units were delineated on black and white vertical aerial photographs at an average scale of 1:32,500. These delineations were then enlarged to a scale of 1:24,000 in order to provide easy comparison with United States Geological Survey (USGS) topographic maps of the park (Figure 167). Complete ground truth for the park consisted of maps of vegetation associations, surface geology and slope. The maps were all brought to a scale of 1:24,000.

The vegetation map describes 139 different associations based on community form and descending order of genera or species dominance by growth form (Interagency Browse Survey Map, 1974). The surface geology map depicts the eight major geological classifications in the park (Goolsby, 1974), and the slope map, prepared from USGS maps, uses three classes to indicate gentle, moderate and steep slopes. (See Appendices K, L, and M for detailed listings of all ground truth factors.)

The four maps--landscape units, vegetation, geology and slope--were overlaid and a composite map was drawn from them. Within each landscape unit, sites were delineated which consisted of one class each of the factors slope, vegetation and geology. Following this,

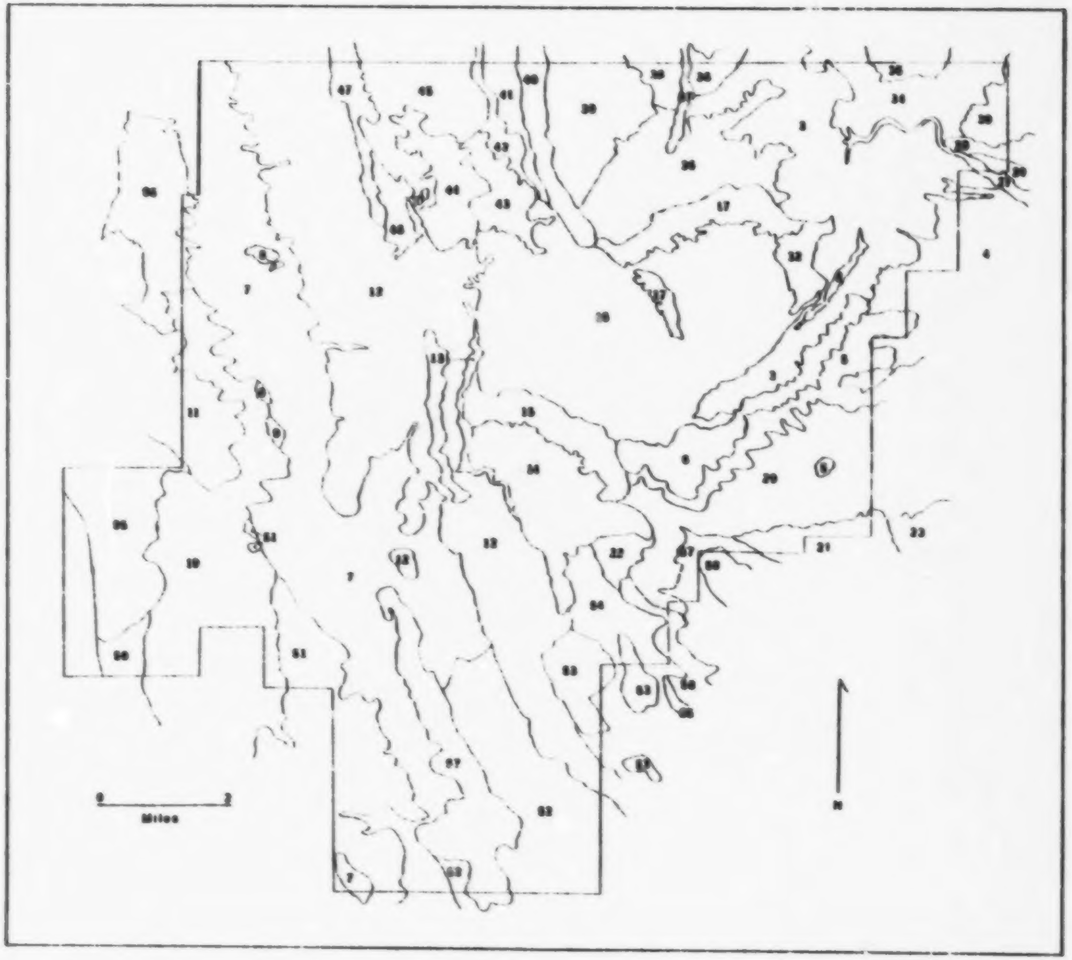

Figure 167. Landscape Units in Guadalupe Mountains National Park.

each landscape unit and its associated sites were mapped separately and the areas of all were measured. A compensating polar planimeter was used which recorded areas in square inches; these were then converted to square miles.

One additional term, the distinct unit, must be defined. A distinct unit consists of one or more sites having the same combination of slope, vegetation and geology. To illustrate this concept, a map of landscape unit 32 is presented on the following page (Figure 158) and a tabular description of each site in that landscape unit is on the next page (Table 145). Each site on the map is numbered and corresponds to the site description in the table. All sites which have identical descriptions within a single landscape unit are combined for the purpose of analysis and the resulting unit is called a distinct unit. This is indicated on the map by assigning each set of identical sites one pattern each. Sites which occur only once are left blank. Brackets are used in the table to show which sites have been combined into distinct units. Distinct units may contain several sites or only one site.

The significance of distinct units lies in the relationship between the total number of sites and the total number of distinct units within a particular landscape unit. In general terms, as the ratio of sites to distinct units increases, there is the implication that repetition is present within the landscape unit. That is to say, the landscape unit is composed of a relatively smaller number of uniquely different sites which are recurring or repeating throughout the landscape unit.

## BOUNDARY TEST

The boundary test was developed to determine if the lines delineated on the aerial photographs represented actual differences between adjacent landscape units. It was done by comparing each physical factor (slope, vegetation and geology) independently. The percent composition for each class of a factor was obtained by dividing the area of a given class by the total area of the appropriate landscape unit. These percent compositions were then paired with the percent compositions of adjacent landscape units. The similarity level was obtained by adding the lower percent composition in each class and summing these (see Table 146).

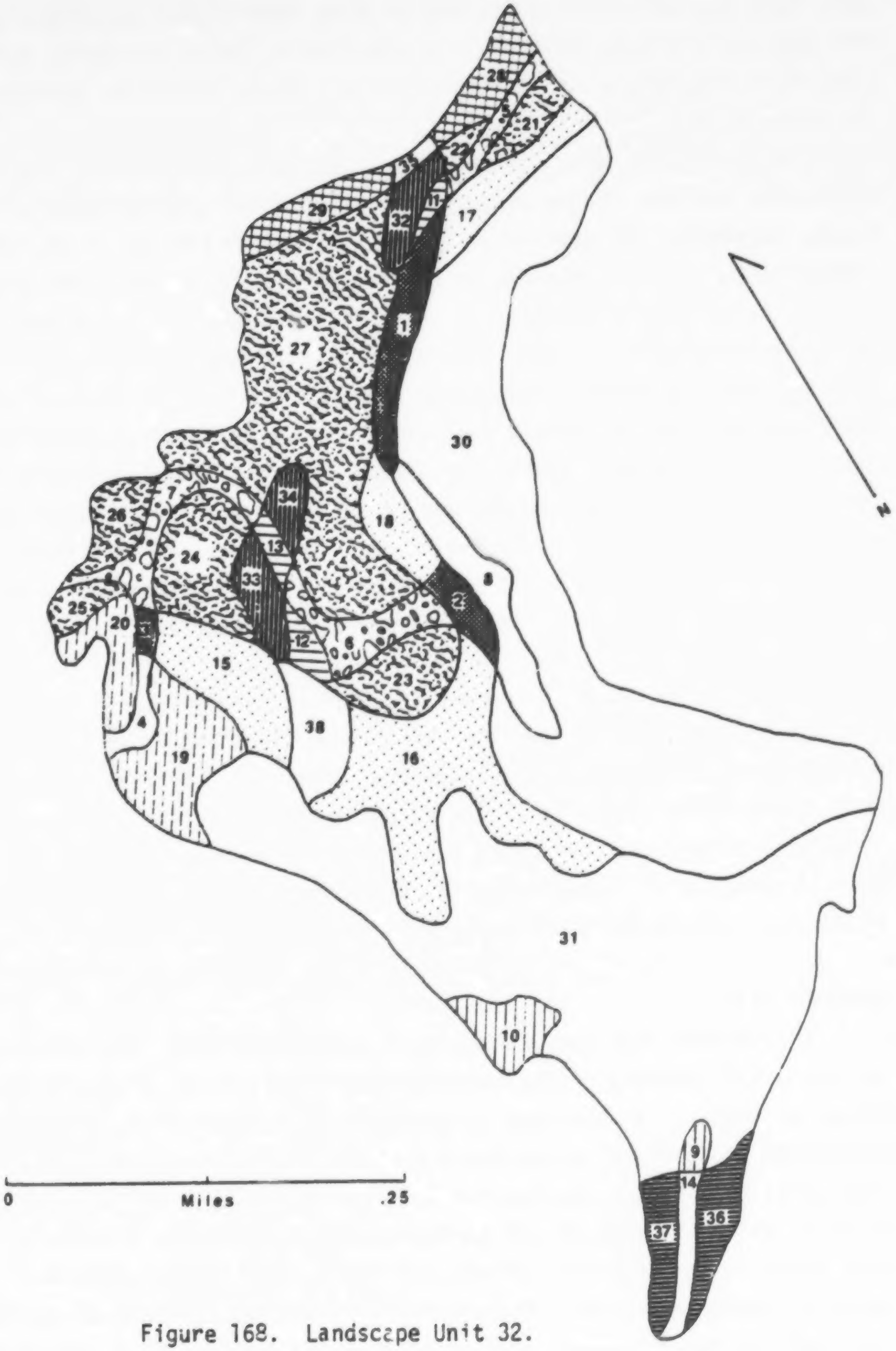

Figure 168. Landscape Unit 32.

## TABLE 145. LANDSCAPE UNIT 32 SITE DESCRIPTIONS

| Site | Area in Square Miles | Slope Factor Classes* | Vegetation Factor Classes* | Geology Factor Classes* | Distinct Unit |
|---|---|---|---|---|---|
| 1 | 0.008 | 5-50 | 10-Acgr-PP-Psme-Arte | M1 | I |
| 2 | 0.005 | 5-50 | 10-Acgr-PP-Psme-Arte | M1 | |
| 3 | 0.002 | 5-50 | 10-Acgr-PP-Psme-Arte | M1 | |
| 4 | 0.004 | 5-50 | 5-Cebr-Cegr-QUER-Dale | M1 | II |
| 5 | 0.007 | 5-50 | 5-Dale-QUER-Cebr-Cegr | M1 | III |
| 6 | 0.010 | 5-50 | 5-Dale-QUER-Cebr-Cegr | M1 | |
| 7 | 0.012 | 5-50 | 5-Dale-QUER-Cebr-Cegr | M1 | |
| 8 | 0.017 | 5-50 | 6-PP-Acgr-Arte-QUER | M1 | IV |
| 9 | 0.002 | 5-50 | 6-PP-Psme-Acgr-QUER | M1 | V |
| 10 | 0.007 | 5-50 | 6-PP-Psme-Acgr-QUER | M1 | |
| 11 | 0.004 | 5-50 | 5-Dale-QUER-Cebr-Cegr | T1 | VI |
| 12 | 0.004 | 5-50 | 5-Dale-QUER-Cebr-Cegr | T1 | |
| 13 | 0.003 | 5-50 | 5-Dale-QUER-Cebr-Cegr | T1 | |
| 14 | 0.004 | 5-50 | 6-PP-Psme-Acgr-QUER | T1 | VII |
| 15 | 0.018 | > 50 | 10-Acgr-PP-Psme-Arte | M1 | VIII |
| 16 | 0.040 | > 50 | 10-Acgr-PP-Psme-Arte | M1 | |
| 17 | 0.010 | > 50 | 10-Acgr-PP-Psme-Arte | M1 | |
| 18 | 0.010 | > 50 | 10-Acgr-PP-Psme-Arte | M1 | |
| 19 | 0.020 | > 50 | 5-Cebr-Cegr-QUER-Dale | M1 | IX |
| 20 | 0.008 | > 50 | 5-Cebr-Cegr-QUER-Dale | M1 | |
| 21 | 0.007 | > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | X |
| 22 | 0.002 | > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | |
| 23 | 0.012 | > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | |
| 24 | 0.017 | > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | |
| 25 | 0.005 | > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | |
| 26 | 0.008 | > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | |
| 27 | 0.070 | > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | |
| 28 | 0.009 | > 50 | 5-Dale-QUER-Cebr-Gawr | M1 | XI |
| 29 | 0.009 | > 50 | 5-Dale-QUER-Cebr-Gawr | M1 | |
| 30 | 0.148 | > 50 | 6-PP-Acgr-Arte-QUER | M1 | XII |

TABLE 145 (Continued)

| Site | Area in Square Miles | Slope Factor Classes* | Vegetation Factor Classes* | Geology Factor Classes* | Distinct Unit |
|---|---|---|---|---|---|
| 31 | 0.154 | > 50 | 6-PP-Psme-Acgr-QUER | M1 | XIII |
| 32 | 0.004 | > 50 | 5-Dale-QUER-Cebr-Cegr | T1 | XIV |
| 33 | 0.008 | > 50 | 5-Dale-QUER-Cebr-Cegr | T1 | |
| 34 | 0.004 | > 50 | 5-Dale-QUER-Cebr-Cegr | T1 | |
| 35 | 0.002 | > 50 | 5-Dale-QUER-Cebr-Cegr | T1 | XV |
| 36 | 0.008 | > 50 | 6-PP-Psme-Acgr-QUER | T1 | XVI |
| 37 | 0.006 | > 50 | 6-PP-Psme-Acgr-QUER | T1 | |
| 38 | 0.012 | > 50 | 10-Acgr-PP-Psme-Arte | T1 | XVII |

*Refer to Appendices K, L, and M for explanation of class terms.

TABLE 146. HYPOTHETICAL SIMILARITY LEVEL TEST FOR SLOPE FACTOR

| Slope Factor Classes* | Landscape Unit A (percent compositions) | Landscape Unit B (percent compositions) | Similarity Level |
|---|---|---|---|
| < 5% | 0 | 0 | 0 |
| 5-50% | 46 | 48 | 46 |
| > 50% | 54 | 52 | 52 |
| | | | 98 |

*Refer to Appendix K for explanation of class terms.

The lower percent composition number in each class of the two landscape units was assumed to represent the greatest degree to which the landscape units were similar, therefore the lower numbers were added and the sum would equal the minimum similarity level between the landscape units for the particular factor being considered. In the example, landscape units A and B would be considered at least 98 percent similar in the slope factor.

Because of the existence of human error as well as the fact that natural boundaries are rarely distinct, it was decided that 10 percent or less dissimilarity would be allowed. To state it another way, if two landscape units had similarity levels of at least 90 percent in all three factors, they would be considered identical and the boundary line would be removed; they would become one landscape unit. If the similarity level was less than 90 percent in at least one factor, the boundary would be deemed real.

Table 147 is an example using all three factors to compare the similarity levels of landscape units A and B. The table shows the percent compositions of each class for the three factors. The similarity levels (obtained by adding the lower number in each class and summing them) for each factor are: slope--98 percent; geology--94 percent; vegetation--22 percent. Although the two landscape units are similar in regard to slope and geology, they are very dissimilar in terms of vegetation composition. This indicates that the vegetation

## TABLE 147. HYPOTHETICAL SIMILARITY LEVEL TEST FOR ALL FACTORS

| | Landscape Unit A | Landscape Unit B | Similarity Level |
|---|---|---|---|
| Slope factor classes* | | | |
| < 5% | 0 | 0 | 0 |
| 5-50% | 46 | 48 | 46 |
| > 50% | 54 | 52 | 52 |
| | | | 98 |
| Geology factor classes* | | | |
| T1 | 88 | 82 | 82 |
| M1 | 3 | 4 | 3 |
| SS | 9 | 14 | 9 |
| | | | 94 |
| Vegetation factor classes* | | | |
| 5-Note-Cebr-Dale-QUER | 14 | 24 | 14 |
| 5-PJ-QUER-Matr-Opim | 44 | 8 | 8 |
| 5-PP-Psme-Acgr-QUER | 0 | 68 | 0 |
| 16-Vist-Latr-Pain-Dale | 42 | 0 | 0 |
| | | | 22 |

*Refer to Appendices K, L, and M for explanation of class terms.

differences were such as to cause some change in the photographic image signature which resulted in the delineation of a boundary. Since there was less than 90 percent similarity in at least one factor, the boundary would be considered to exist. The fact that the same vegetation occurs in both landscape units does not reduce the quality of the result since, as has been pointed out, boundaries are rarely distinct; identical factors may range across boundaries; and different factors will dominate in different places.

## SIMILARITY TESTS

The landscape units were tested for similarity using ground truth data as a means of verifying the qualitative results of the photo interpretation which indicated that each landscape unit was visually different from all others in the park in terms of tone, texture and pattern.

A pairwise comparison of all landscape units was made using the percent compositions of the classes for the slope, vegetation and geology factors (each factor being tested separately). If two landscape units had similarity levels of at least 90 percent in all three factors, then they would have been considered similar. If there was less than 90 percent similarity in at least one factor, the landscape units would be considered unique.

The reason for choosing the 90 percent level in both cases was to make a stringent test for similarity. Because mountain landscapes have such variety, different management practices may be essential for protection and enjoyment. In other words, if a lower level of agreement was accepted, some landscape units might appear similar, yet if managed the same, serious harm could result. Thus an initially stringent test allows a margin of safety which can later be relaxed if more detailed study so indicates.

One important aspect of the similarity level test was to determine to what degree the landscape units were dissimilar. It was decided that they had to be more than 10 percent dissimilar to be considered unique, but if all the landscape units evidenced greater degrees of dissimilarity this would further support the contention that the delineated units were unique. This was accomplished by choosing the pair of landscape units which had the highest percent compositions in all three factors. For this pair, the lowest percent composition of the three factors was subtracted from 100 percent and the result was the absolute minimum degree of dissimilarity among all pairs of landscape units. For example, if the landscape unit pair having the highest percent compositions in all three factors had these similarity values: 60 percent, 100 percent and 100 percent in vegetation, slope and geology respectively, then by subtracting 60 percent from 100 percent the result would be 40 percent dissimilarity. Obviously for any other landscape unit pair having percent compositions less than those in the example, the result would be greater dissimilarity.

Because of the variety within the landscape units it was possible that two might appear unique using the similarity levels of slope, vegetation and geology separately, and yet they might be similar in terms of the dominant distinct units, i.e., those distinct units whose areas summed to 50 percent or more of a landscape unit area. As a result, all landscape unit pairs were further tested for uniqueness using the descriptions of the dominant distinct units. Landscape units were considered unique if the dominant distinct units occurred only once among all 46 landscape units. If a particular dominant distinct unit occurred in more than one landscape unit and it was the only dominant distinct unit in each landscape unit, then the landscape units would be considered similar. For example:

TABLE 148. HYPOTHETICAL COMPARISON OF DOMINANT DISTINCT UNITS

| Distinct Unit | | | Landscape Unit | Percent of Landscape Unit |
|---|---|---|---|---|
| Slope* | Vegetation* | Geology* | | |
| > 50 | 16-Dale-Vist-Pain-Fosp-1 | Tl | A | 53 |
| 5-50 | 5-Dale-QUER-Rhtr-Mibi | Qc | B | 67 |
| 5-50 | 5-Dale-QUER-Rhtr-Mibi | Qc | C | 72 |
| 5-50 | 5-Dale-QUER-Rhtr-Mibi | Qc | D | 35 |
| < 5 | 5-Note-Dale-QUER-Cebr | Ml | D | 21 |

*Refer to Appendices K, L, and M for explanation of class terms.

Assuming landscape units A, B, C and D are the only ones being studied, it can be seen from the table that landscape unit A is unique from all others because its dominant distinct unit is different. Landscape units B and C are similar because their dominant distinct units are the same and each of them is the only distinct unit in both landscape units (they are the only ones because each is more than 50 percent of its respective landscape unit and it took only one distinct unit in each case to meet the criterion). Landscape unit D is not similar to B and C because, though it has one dominant distinct unit which is the same as those of B and C, that is not the only distinct unit in the landscape unit. It required one other landscape unit to make up 50 percent or more of landscape unit D's area.

## HOMOGENEITY TESTS

Closely associated with the concept of uniqueness is the concept of internal homogeneity of the designated landscape units. From the standpoint of utility and viability of landscape units as management entities, there exists an implicit requirement that the delineated landscape units display a greater level of homogeneity than would a series of randomly configured units of comparable size. That is to say, the landscape units should be so configured that the variability or variance which is inherent within the park, is distributed between the units rather than within units. A set of randomly configured units would not be expected to significantly reduce the internal unit variability.

In this case, the specific level of homogeneity is not an issue so long as the delineated landscape units are internally more homogeneous than randomly configured units. In order to develop hypotheses and tests, certain logical consequences for various situations had to be postulated.

Given the great diversity of slope, vegetation, and geology in the landscape units and the range of sizes (areal extent), some means of analyzing the site composition of landscape units had to be devised which would accommodate and yet not make size a limiting criterion.*

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*If the size of a landscape unit were the determinant factor in landscape unit analysis, then every landscape unit would have to be analyzed individually which would preclude a synthesis of information and thus eliminate the landscape unit concept as a predictive tool.

A totally homogeneous landscape unit is one which, throughout its extent, is made up of only one combination of slope, vegetation and geology. Thus it would have one site and one distinct unit. A totally heterogeneous landscape unit would have many singular sites and an equal number of distinct units.

Sites, although not defined in terms of areal extent, are generally much smaller than individual landscape units, therefore, increases in landscape unit size are a function of increasing numbers of sites being assigned to or included within a particular landscape unit. The key element then, in evaluating homogeneity for a given landscape unit or for a series of units, becomes a matter of evaluating site repetitiveness within the units.

If a landscape unit were to approach homogeneity: (1) sites would have to become repetitious; (2) the number of distinct units per unit area would not increase at a rate equal to the rate of area increase; (3) the number of dominant distinct units would tend to remain low.

In order to test the theory that the delineated landscape units are, in fact, entities which display a greater degree of internal homogeneity than would comparably sized randomly configured units, three minor hypotheses were developed. These null hypotheses were constructed assuming that the delineated units were not effective in reducing internal homogeneity; that is, they were no better than a series of randomly drawn units.

(a) The number of distinct units per unit area was independent of landscape unit size.

(b) The number of sites per dominant distinct unit was independent of landscape unit size.

(c) The ratio of dominant distinct units to total number of distinct units in a landscape unit was independent of landscape unit size.

These three hypotheses were tested using Hotelling and Pabst's Test for Rank-Order Correlation with $H_0 :: p = 0$ (Bradley, 1962). Rejection of the null hypothesis (the variables are independent) points to acceptance of two possible alternative hypotheses, namely: there is a positive or negative correlation between the variables. Inferences based upon these alternatives are discussed in the Results and Discussion section.

A caveat must be inserted at this point concerning hypothesis (b). A paradox arises when totally homogeneous landscape units and totally heterogeneous landscape units are tested. Since the totally homogeneous landscape unit would have one site and one dominant distinct unit, the ratio of the number of sites per dominant distinct units would be 1. In contrast, a completely heterogeneous landscape unit would have many unique sites and an equal number of distinct units. As a result, the ratio of the number of sites to dominant distinct units would also equal 1. Thus both the homogeneous and heterogeneous landscape units would have the same ratio value. Apart from these two exceptions, and remembering that they deal with models rather than reality, the tests presented appear to be a viable means of evaluating the hypotheses.

## RESULTS AND DISCUSSION

The methodology of the boundary test has been described; in essence it assumes that a boundary exists if at least one of the factors used (slope, vegetation, geology) has a similarity level of less than 90 percent between two adjacent landscape units. Tables 149, 150 and 151 present the pairwise comparisons for all possible pairs of landscape units for each of the factors, slope, vegetation and geology, respectively. Only those pairs which formed a boundary with each other were used in this test and are designated in the table by an asterisk. Several pairs showed high degrees of similarity in two factors, but at least one factor in each case has a low level of similarity. Thus the first major hypothesis, that the boundaries delineated using aerial photographs were real, was verified.

Similarity of all landscape units was tested in two ways. First, all landscape units were compared by pairing each landscape unit with every other landscape unit to find the individual similarity levels for slope, vegetation and geology. In every case, at least one and often two factors exhibited similarity levels of less than 90 percent. Additionally, the least degree of dissimilarity that occurred was 39 percent in the landscape unit pair 11 and 95, thus indicating that not only were the landscape unit pairs not similar, but they were dissimilar at a minimum of 39 percent.

## TABLE 149. PAIRWISE COMPARISON FOR SLOPE FACTOR (MINIMUM PERCENT AGREEMENT)

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 20 | 21 | 22 | 23 | 27 | 28 | 29 | 30 | 32 | 34 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 50 | 51 | 52 | 53 | 54 | 57 | 58 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | 80* | 0 | 42 | 95 | 4 | 0 | 0 | 1 | 0 | 58 | 99 | 84 | 69 | 39 | 83 | 1 | 0 | 92 | 0 | 3 | 0 | 0 | 0 | 87 | 83 | 54 | 89 | 29 | 48 | 64 | 1 | 0 | 32 | 3 | 1 | 1 | 38 | 0 | 54 | 5 | 57 | 61 | 28 | 14 | 0 |
| 3 | | | 20* | 62 | 85* | 24 | 20 | 20 | 11 | 0 | 79 | 81 | 96 | 89 | 59* | 97* | 21 | 4 | 86 | 20 | 23* | 20 | 20 | 19 | 93* | 97* | 74* | 91* | 49 | 68 | 84 | 21 | 21 | 52 | 23 | 21 | 21 | 58 | 0 | 74 | 25 | 72 | 81 | 48 | 34 | 0 |
| 4 | | | | 58* | 5* | 86 | 100 | 100 | 10 | 0 | 41 | 1 | 16 | 31 | 60 | 17 | 73 | 4 | 8 | 26 | 97* | 100 | 100 | 100 | 13 | 17 | 47 | 11 | 71 | 52 | 36 | 99 | 98 | 68 | 94 | 89 | 79 | 62 | 0 | 22 | 57 | 48 | 39 | 61 | 86 | 0 |
| 5 | | | | | 47* | 62 | 58 | 58 | 11 | 0 | 81 | 43 | 58 | 73* | 97 | 59 | 59* | 4 | 50 | 28 | 61 | 58 | 58 | 58 | 55 | 59 | 89 | 53 | 87 | 94 | 78 | 58 | 59 | 90 | 61 | 59 | 59 | 96 | 0 | 64 | 61 | 90 | 81 | 86 | 72 | 0 |
| 6 | | | | | | 8 | 5 | 5 | 6 | 0 | 64 | 97 | 88 | 74* | 44* | 88 | 6 | 4 | 96 | 5 | 8 | 5 | 5 | 5 | 92 | 97 | 58 | 94 | 33 | 52 | 69 | 6 | 6 | 37 | 8 | 6 | 6 | 41 | 0 | 59 | 9 | 57 | 65 | 33 | 19 | 0 |
| 7 | | | | | | | 66* | 66* | 41* | 80 | 45* | 5 | 20 | 35 | 64 | 21 | 94 | 38 | 12 | 58 | 70 | 66 | 66 | 66 | 17 | 20 | 50 | 15 | 70 | 56 | 39 | 68 | 69 | 70 | 72 | 77 | 87 | 66 | 38 | 49* | 90* | 51 | 43 | 75* | 70 | 90* |
| 8 | | | | | | | | 100 | 10 | 0 | 41 | 1 | 16 | 31 | 60 | 17 | 73 | 4 | 8 | 26 | 97 | 100 | 100 | 106 | 13 | 17 | 47 | 11 | 71 | 52 | 36 | 99 | 98 | 68 | 94 | 89 | 79 | 62 | 0 | 22 | 57 | 48 | 39 | 61 | 86 | 0 |
| 9 | | | | | | | | | 100* | 0 | 41 | 1 | 16 | 31 | 60 | 17 | 73 | 4 | 8 | 28 | 97 | 100 | 100 | 100 | 13 | 17 | 47 | 11 | 71 | 52 | 36 | 99 | 98 | 68 | 94 | 89 | 79 | 62 | 0 | 22 | 57 | 48 | 39 | 61 | 86 | 0 |
| 10 | | | | | | | | | | 89* | 12 | 2 | 11 | 11 | 12 | 11 | 38 | 93 | 9 | 83 | 11 | 10 | 10 | 10 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 13 | 11 | 14 | 21 | 31 | 11 | 89* | 35* | 50 | 11 | 11 | 22 | 11 | 89* |
| 11 | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 96 | 0 | 72 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 10 | 20 | 0 | 100 | 24 | 39 | 0 | 0 | 10 | 0 | 100* |
| 12 | | | | | | | | | | | | 60* | 76* | 90 | 80* | 76 | 42 | 4 | 68 | 28 | 44 | 41 | 41 | 41 | 72 | 76 | 94 | 70 | 69 | 88 | 95 | 42 | 42 | 73 | 44* | 41 | 42* | 78* | 0 | 77 | 45* | 93* | 98* | 69 | 54 | 0 |
| 13 | | | | | | | | | | | | | 85* | 70* | 41* | 85 | 2 | 1 | 93 | 1 | 4 | 1 | 1 | 1 | 88 | 85 | 55 | 90 | 30 | 49 | 66 | 3 | 2 | 33 | 5 | 2 | 2 | 39 | 0 | 56 | 6 | 54 | 62 | 30 | 15 | 0 |
| 14 | | | | | | | | | | | | | | 85* | 56 | 100 | 17* | 8 | 92* | 16 | 20 | 16 | 16 | 16 | 97 | 100 | 70 | 95 | 45 | 64 | 81 | 18 | 17 | 48 | 20 | 17 | 17 | 54 | 0 | 71 | 21 | 69 | 77* | 45 | 30 | 0 |
| 15 | | | | | | | | | | | | | | | 71* | 86 | 32* | 4 | 77 | 28 | 5 | 31 | 31 | 31 | 82 | 86 | 86 | 80 | 60 | 79 | 96 | 33 | 32 | 63 | 35 | 32 | 32 | 69 | 0 | 76 | 36 | 88 | 92 | 60 | 45 | 0 |
| 16 | | | | | | | | | | | | | | | | 56* | 62 | 5 | 48 | 28 | 63 | 60 | 60 | 60 | 52* | 56 | 86 | 50 | 88 | 92 | 75* | 62* | 62* | 92* | 64* | 62 | 62 | 98 | 0 | 62 | 62 | 87 | 79 | 89 | 74 | 0 |
| 17 | | | | | | | | | | | | | | | | | 17 | 4 | 92 | 17 | 20 | 17 | 17 | 17 | 96* | 100 | 70* | 94 | 45 | 64 | 81* | 19 | 18 | 49 | 20 | 18 | 18 | 55 | 0 | 71 | 21 | 69 | 78 | 45 | 31 | 0 |
| 20 | | | | | | | | | | | | | | | | | | 31* | 9* | 54* | 74 | 73 | 73 | 73 | 14 | 18 | 46 | 12 | 73 | 54 | 37 | 74 | 75 | 69 | 76 | 81 | 93 | 63 | 26 | 47 | 88 | 49 | 40 | 73* | 74* | 21 |
| 21 | | | | | | | | | | | | | | | | | | | 4 | 77* | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 6 | 4 | 7 | 14 | 24 | 4 | 96 | 28 | 43 | 4 | 4 | 14* | 4 | 96 |
| 22 | | | | | | | | | | | | | | | | | | | | 8 | 11 | 8 | 8 | 8 | 95 | 92 | 62 | 97 | 37 | 56 | 73 | 10 | 9 | 60 | 12 | 10 | 10 | 46 | 0 | 63 | 13 | 61 | 64* | 37 | 22* | 0 |
| 23 | | | | | | | | | | | | | | | | | | | | | 27 | 28 | 27 | 27 | 13 | 17 | 28 | 11 | 28 | 28 | 28 | 28 | 29 | 28 | 30 | 37 | 47 | 28 | 72 | 46 | 66 | 28 | 28 | 38 | 28 | 72 |
| 27 | | | | | | | | | | | | | | | | | | | | | | 97* | 97* | 97 | 16 | 20* | 50 | 14 | 75 | 56 | 30 | 98 | 98 | 71 | 98 | 90 | 81 | 66 | 0 | 25 | 60 | 51 | 43 | 65 | 90 | 0 |
| 28 | | | | | | | | | | | | | | | | | | | | | | | 100* | 100 | 13 | 17 | 47 | 11 | 71 | 52 | 36 | 99 | 98 | 68 | 94 | 89 | 79 | 62 | 0 | 22 | 57 | 48 | 39 | 61 | 86 | 0 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | 100* | 13 | 17* | 47 | 11 | 71 | 52 | 36 | 99 | 98 | 68 | 94 | 89 | 79 | 62 | 0 | 22 | 57 | 48 | 39 | 61 | 86 | 0 |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | 13 | 17* | 47 | 11 | 71 | 52 | 36 | 99 | 98 | 68 | 94 | 89 | 79 | 62 | 0 | 22 | 57 | 48 | 39 | 61 | 86 | 0 |
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | | 96 | 67 | 98 | 42 | 61 | 78 | 15 | 14 | 45 | 16 | 14 | 14 | 51 | 0 | 67 | 18 | 65 | 74 | 42 | 27 | 0 |
| 34 | | | | | | | | | | | | | | | | | | | | | | | | | | | 70 | 94 | 45 | 64 | 81 | 18 | 18 | 49 | 20 | 18 | 18 | 55 | 0 | 71 | 21 | 69 | 76 | 45 | 31 | 0 |
| 36 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 64* | 75* | 94* | 69* | 48 | 48 | 78 | 50 | 48 | 48 | 84 | 0 | 76 | 51 | 99 | 93 | 75 | 60 | 0 |
| 37 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 40* | 56 | 75 | 12 | 12 | 43 | 14 | 12 | 12 | 49 | 0 | 65 | 16 | 63 | 72 | 94 | 75 | 0 |
| 38 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 81* | 64 | 73 | 72 | 97 | 75 | 73 | 73 | 91 | 0 | 51 | 61 | 76 | 68 | 90 | 85 | 0 |
| 39 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 83* | 54 | 53 | 88 | 56 | 54 | 54 | 90 | 0 | 70 | 57 | 95 | 87 | 81 | 66 | 0 |
| 40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 37* | 37 | 68 | 39 | 37 | 37 | 73 | 0 | 76 | 40 | 88 | 96 | 64 | 50 | 0 |
| 41 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 99* | 69 | 96 | 90 | 81 | 64 | 0 | 24 | 58 | 49 | 41 | 63 | 88 | 0 |
| 42 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 69* | 96 | 97* | 82 | 63 | 1 | 24 | 59 | 49 | 40 | 64 | 87 | 1 |
| 43 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 71* | 69* | 69 | 94 | 0 | 54 | 61 | 80 | 71 | 90 | 82 | 0 |
| 44 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 93* | 83* | 65 | 2 | 27 | 63 | 51 | 43 | 67 | 90 | 2 |
| 45 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 90* | 63* | 10 | 33 | 68 | 49 | 40 | 72 | 87 | 9 |
| 46 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 63* | 20 | 43 | 77 | 49 | 40 | 73 | 81 | 20 |
| 47 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 60 | 61 | 86 | 77 | 90 | 76 | 0 |
| 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 24 | 32 | 0 | 0 | 10 | 0 | 100* |
| 51 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 50 | 74 | 76 | 61 | 36 | 24 |
| 52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 52 | 44 | 72* | 61 | 39 |
| 53 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 92* | 76 | 62 | 0 |
| 54 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 68 | 53* | 0 |
| 57 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 75* | 10 |
| 58 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 95 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

* Indicates *Landscape* units having a common boundary.

## TABLE 150. PAIRWISE COMPARISON FOR VEGETATION FACTOR (MINIMUM PERCENT AGREEMENT)

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 20 | 21 | 22 | 23 | 27 | 28 | 29 | 30 | 32 | 34 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 50 | 51 | 52 | 53 | 54 | 57 | 58 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | 35* | 11 | 3 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 27 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 56 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | | | 17* | 4 | 18* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1* | 22* | 0 | 0 | 0 | 0 | 13* | 0 | 2 | 0 | 27* | 8* | 17* | 16* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | | | | 22* | 6* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 10* | 0 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | | | | | 17* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 14* | 11 | 0 | 10 | 2 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 6 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3* | 3* | 25 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 29 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | | | | | | | 32* | 21* | 16* | 6 | 11* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22* | 8* | 0 | 0 | 23* | 0 | 19* |
| 8 | | | | | | | | 16 | 9 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 0 | 0 | 8 | 0 | 21 |
| 9 | | | | | | | | | 11* | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 0 | 0 | 8 | 0 | 0 |
| 10 | | | | | | | | | | 35* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22* | 10* | 4 | 0 | 0 | 8 | 0 | 43* |
| 11 | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 2 | 0 | 61* |
| 12 | | | | | | | | | | | | 20* | 4* | 4 | 3* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4* | 7 | 5* | 9* | 0 | 1 | 7* | 4* | 8* | 12 | 1 | 0 |
| 13 | | | | | | | | | | | | | 21* | 22* | 16* | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 14 | | | | | | | | | | | | | | 19* | 12 | 0 | 3* | 1 | 14* | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13* | 1 | 1 | 0 |
| 15 | | | | | | | | | | | | | | | 19* | 1 | 0* | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 5 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 16 | | | | | | | | | | | | | | | | 18* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32* | 1 | 22 | 1 | 1 | 1 | 4* | 2* | 2* | 6* | 3* | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | | | | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31* | 0 | 19* | 28 | 28 | 0 | 8* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | | | | | | | | | | | | | | | | | | 27* | 7* | 23* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 13* | 9* | 0 |
| 21 | | | | | | | | | | | | | | | | | | | 0 | 67* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6* | 0 | 0 |
| 22 | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 39* | 0 | 16* | 0 |
| 23 | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 27 | | | | | | | | | | | | | | | | | | | | | | 7* | 27* | 0 | 18 | 5* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | | | | | | | | | | | | | | | | | | | | | | | 60* | 91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | 53* | 1 | 19* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 8* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 20* | 7* | 7* | 1* | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 25* | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 22* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10* | 6 | 6 | 4 | 6 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 40* | 36 | 61 | 22 | 13 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 33* | 13 | 11 | 13 | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 32* | 23 | 20* | 16 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 43 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 24* | 6* | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 12* | 16* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 27* | 16* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 46 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 42* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 12* |
| 51 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 0 | 0 | 13 | 0 | 0 |
| 52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 4 | 17* | 0 | 0 |
| 53 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10* | 0 | 2 | 0 |
| 54 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 25* | 0 |
| 57 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 23* | 0 |
| 58 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 95 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

* Indicates landscape units having a common boundary.

# TABLE 151. PAIRWISE COMPARISON FOR GEOLOGY FACTOR (MINIMUM PERCENT AGREEMENT)

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 20 | 21 | 22 | 23 | 27 | 28 | 29 | 30 | 32 | 34 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 50 | 51 | 52 | 53 | 54 | 57 | 58 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | 93* | 9 | 19 | 77 | 27 | 61 | 77 | 4 | 1 | 64 | 83 | 79 | 89 | 65 | 85 | 3 | 0 | 82 | 0 | 66 | 23 | 31 | 37 | 86 | 86 | 27 | 23 | 56 | 25 | 25 | 53 | 44 | 35 | 44 | 61 | 86 | 96 | 0 | 59 | 11 | 0 | 34 | 24 | 23 | 0 |
| 3 | | | 12* | 70 | 80* | 32 | 55 | 79 | 5 | 2 | 65 | 82 | 82 | 90 | 60* | 79* | 8 | 3 | 67 | 4 | 71* | 18 | 26 | 33 | 80* | 89* | 22* | 16* | 52 | 21 | 18 | 49 | 40 | 32 | 39 | 58 | 89 | 95 | 2 | 62 | 16 | 4 | 37 | 29 | 21 | 2 |
| 4 | | | | 52* | 12* | 14 | 9 | 0 | 1 | 1 | 32 | 24 | 14 | 19 | 13 | 9 | 79 | 57 | 16 | 67 | 36* | 20 | 26 | 26 | 9 | 9 | 23 | 9 | 33 | 20 | 9 | 18 | 12 | 17 | 26 | 12 | 22 | 9 | 0 | 4 | 34 | 34 | 45 | 36 | 27 | 0 |
| 5 | | | | | 13* | 15 | 19 | 1 | 1 | 1 | 38 | 34 | 14 | 27* | 23 | 20 | 33* | 14 | 17 | 24 | 40 | 30 | 32 | 31 | 9 | 10 | 32 | 19 | 30 | 31 | 19 | 20 | 22 | 27 | 32 | 22 | 26 | 19 | 0 | 5 | 25 | 24 | 47 | 34 | 33 | 0 |
| 6 | | | | | | 20 | 38 | 88 | 3 | 0 | 47 | 66 | 97 | 82* | 42* | 63 | 6 | 0 | 91 | 0 | 50 | 0 | 0 | 15 | 80 | 80 | 4 | 0 | 33 | 2 | 2 | 31 | 21 | 12 | 21 | 39 | 74 | 82 | 0 | 57 | 2 | 0 | 29 | 38 | 1 | 0 |
| 7 | | | | | | | 54* | 19* | 69* | 66 | 37* | 30 | 22 | 29 | 30 | 28 | 15 | 5 | 28 | 6 | 40 | 11 | 18 | 36 | 27 | 27 | 15 | 8 | 33 | 16 | 10 | 30 | 52 | 33 | 30 | 40 | 30 | 27 | 65 | 67* | 80* | 6 | 34 | 70* | 18 | 65* |
| 8 | | | | | | | | 38 | 30 | 27 | 60 | 57 | 40 | 54 | 74 | 74 | 8 | 0 | 43 | 0 | 61 | 35 | 43 | 59 | 47 | 47 | 39 | 35 | 60 | 37 | 38 | 66 | 70 | 58 | 56 | 83 | 51 | 57 | 27 | 67 | 38 | 0 | 34 | 51 | 38 | 27 |
| 9 | | | | | | | | | 3* | 0 | 45 | 64 | 86 | 73 | 42 | 63 | 0 | 0 | 84 | 0 | 50 | 0 | 0 | 15 | 91 | 91 | 4 | 0 | 33 | 2 | 2 | 30 | 21 | 12 | 21 | 39 | 73 | 82 | 0 | 56 | 2 | 0 | 19 | 22 | 0 | 0 |
| 10 | | | | | | | | | | 97* | 6 | 4 | 4 | 4 | 4 | 4 | 7 | 0 | 4 | 0 | 10 | 1 | 4 | 13 | 4 | 4 | 4 | 1 | 4 | 3 | 3 | 4 | 26 | 15 | 4 | 14 | 4 | 4 | 96* | 43* | 67 | 0 | 4 | 46 | 7 | 96* |
| 11 | | | | | | | | | | | 3 | 1 | 1 | 1 | 1 | 1 | 7 | 0 | 1 | 0 | 7 | 1 | 1 | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 23 | 11 | 1 | 11 | 1 | 1 | 99 | 40 | 65 | 0 | 1 | 43 | 7 | 96* |
| 12 | | | | | | | | | | | | 81* | 50* | 65 | 66* | 65 | 27 | 6 | 57 | 16 | 84 | 31 | 45 | 41 | 54 | 54 | 37 | 20 | 65 | 33 | 22 | 50 | 47 | 42 | 50* | 64 | 72* | 63* | 2 | 51 | 21* | 22* | 60* | 40 | 41 | 2 |
| 13 | | | | | | | | | | | | | 69* | 82* | 65* | 82 | 18 | 2 | 76 | 12 | 79 | 31 | 39 | 34 | 73 | 73 | 36 | 19 | 60 | 20 | 21 | 58 | 42 | 39 | 52 | 60 | 90 | 83 | 0 | 59 | 14 | 13 | 49 | 33 | 32 | 0 |
| 14 | | | | | | | | | | | | | | 84* | 44 | 65 | 9* | 1 | 93* | 0 | 53 | 3 | 10 | 17 | 80 | 80 | 6 | 2 | 36 | 5 | 4 | 33 | 23 | 14 | 23 | 41 | 76 | 84 | 0 | 59 | 5 | 1 | 31* | 36 | 3 | 0 |
| 15 | | | | | | | | | | | | | | | 58* | 79 | 11* | 2 | 86 | 2 | 68 | 16 | 24 | 33 | 82 | 83 | 20 | 16 | 51 | 20 | 18 | 47 | 37 | 20 | 37 | 55 | 86 | 80 | 0 | 60 | 13 | 2 | 44 | 35 | 10 | 0 |
| 16 | | | | | | | | | | | | | | | | 79* | 7 | 2 | 51 | 4 | 62 | 56 | 66 | 69 | 51* | 51 | 62 | 54 | 80 | 60 | 56* | 80* | 78* | 70* | 79* | 90 | 59 | 60 | 0 | 45 | 14 | 4 | 38 | 28 | 36 | 0 |
| 17 | | | | | | | | | | | | | | | | | 3 | 0 | 68 | 0 | 67 | 37 | 45 | 52 | 71* | 72 | 41* | 37 | 70 | 39 | 39* | 60 | 58 | 49 | 56 | 76 | 76 | 81 | 0 | 50 | 12 | 0 | 34 | 24 | 33 | 0 |
| 20 | | | | | | | | | | | | | | | | | | 72* | 13* | 82* | 35 | 14 | 18 | 26 | 3 | 3 | 16 | 3 | 27 | 14 | 3 | 12 | 11 | 17 | 18 | 12 | 16 | 3 | 6 | 10 | 33 | 32 | 34 | 34* | 26* | 6 |
| 21 | | | | | | | | | | | | | | | | | | | 2 | 90* | 13 | 2 | 2 | 17 | 0 | 0 | 2 | 0 | 18 | 6 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 1 | 24 | 19 | 12 | 16* | 3 | 0 |
| 22 | | | | | | | | | | | | | | | | | | | | 4 | 60 | 19 | 17 | 20 | 80 | 80 | 14 | 5 | 43 | 12 | 8 | 40 | 29 | 22 | 30 | 47 | 83 | 87 | 8 | 59 | 10 | 4 | 35* | 35 | 10* | 0 |
| 23 | | | | | | | | | | | | | | | | | | | | | 23 | 12 | 12 | 17 | 0 | 0 | 12 | 0 | 24 | 12 | 0 | 9 | 3 | 8 | 12 | 3 | 12 | 0 | 0 | 1 | 25 | 29 | 22 | 21 | 13 | 0 |
| 27 | | | | | | | | | | | | | | | | | | | | | | 28* | 41* | 48 | 59 | 59* | 34 | 36 | 68 | 30 | 10 | 56 | 46 | 42 | 54 | 64 | 77 | 66 | 6 | 60 | 31 | 28 | 60 | 48 | 40 | 6 |
| 28 | | | | | | | | | | | | | | | | | | | | | | | 82* | 59 | 9 | 9 | 94 | 88 | 51 | 94 | 86 | 70 | 57 | 78 | 73 | 52 | 25 | 18 | 8 | 3 | 12 | 12 | 27 | 9 | 44 | 0 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | 67* | 16 | 17* | 88 | 70 | 58 | 79 | 72 | 77 | 65 | 85 | 87 | 59 | 34 | 26 | 0 | 11 | 14 | 22 | 45 | 17 | 54 | 0 |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | 23 | 24* | 63 | 58 | 79 | 66 | 62 | 74 | 78 | 80 | 74 | 72 | 28 | 33 | 8 | 28 | 37 | 17 | 39 | 39 | 40 | 9 |
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | | 100 | 13 | 9 | 42 | 11 | 11 | 39 | 30 | 21 | 30 | 47 | 82 | 90 | 0 | 59 | 10 | 0 | 27 | 24 | 9 | 0 |
| 34 | | | | | | | | | | | | | | | | | | | | | | | | | | | 13 | 9 | 42 | 11 | 11 | 40 | 30 | 21 | 30 | 40 | 83 | 91 | 0 | 59 | 11 | 0 | 28 | 24 | 9 | 0 |
| 36 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 82* | 55* | 92* | 85* | 73 | 61 | 81 | 79 | 55 | 30 | 22 | 0 | 7 | 14 | 14 | 32 | 13 | 46 | 0 |
| 37 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 43* | 86 | 90 | 60 | 54 | 69 | 61 | 49 | 13 | 18 | 0 | 3 | 9 | 0 | 15 | 2 | 32 | 0 |
| 38 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 57* | 45 | 82 | 67 | 63 | 72 | 79 | 54 | 52 | 0 | 37 | 30 | 24 | 51 | 45 | 41 | 0 |
| 39 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 88* | 70 | 59 | 79 | 70 | 54 | 22 | 20 | 0 | 6 | 19 | 12 | 29 | 15 | 41 | 0 |
| 40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 63* | 57 | 72 | 63 | 51 | 16 | 21 | 0 | 5 | 11 | 0 | 17 | 4 | 32 | 0 |
| 41 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 70* | 80 | 90 | 82 | 53 | 40 | 0 | 33 | 14 | 9 | 43 | 31 | 42 | 0 |
| 42 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 80* | 70 | 82* | 37 | 30 | 22 | 46 | 36 | 3 | 36 | 40 | 41 | 22 |
| 43 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 81* | 73* | 33 | 30 | 11 | 25 | 25 | 8 | 35 | 31 | 46 | 11 |
| 44 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 72* | 40* | 30 | 0 | 24 | 14 | 18 | 52 | 30 | 50 | 0 |
| 45 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 55* | 57* | 10 | 51 | 24 | 3 | 37 | 37 | 41 | 10 |
| 46 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 86* | 0 | 58 | 14 | 14 | 45 | 31 | 27 | 0 |
| 47 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 59 | 11 | 0 | 34 | 24 | 18 | 0 |
| 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 40 | 64 | 0 | 0 | 42 | 6 | 100* |
| 51 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 45 | 1 | 23 | 65 | 10 | 40 |
| 52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 20 | 24 | 63* | 20 | 64 |
| 53 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 54* | 21 | 61 | 0 |
| 54 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 47 | 61* | 0 |
| 57 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 16* | 42 |
| 58 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 95 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

* Indicates landscape units having a common boundary.

Second, the dominant distinct units, those whose areas summed to at least 50 percent of a landscape unit, were listed and their descriptions, using slope, vegetation and geology simultaneously, were compared with all other dominant distinct units (Table 152). This was an additional check on the individual similarity tests, because it was possible that two landscape units might appear to be unique in terms of the individual factors, but might be similar if they each only had a single identical dominant distinct unit. With the exception of three landscape unit pairs: 21 and 23; 28 and 30; 11 and 95, all other landscape units were found to be unique in terms of dominant distinct units.

Considering the fact that there were 1425 possible pairs of landscape units to be evaluated in the uniqueness testing, it is remarkable that in only three cases were pairs discovered which could not clearly be designated as singularly unique. Further examination of these three pairs revealed that, while each pair did in fact have a single identical dominant distinct unit, the site distribution caused a sufficiently different pattern (on the aerial photographs) between members of a pair to be indicative of a "uniqueness" which could possibly be of significance in the management of these areas. Therefore, it was deemed desirable to consider these landscape units to be unique at this time.

The third major hypothesis dealt with the internal homogeneity of the landscape units and this was examined by postulating three minor hypotheses, all of which were tested using Hotelling and Pabst's Test for Rank-Order Correlation (Bradley, 1968). (See Appendices N and O).

The first null hypothesis postulated that: the number of distinct units per unit area was independent of landscape unit size. A negative correlation (r = -0.57) was obtained, and the null hypothesis was rejected. The alternative hypothesis of negative correlation was accepted. The result indicated that as landscape unit area increased, more repetitive sites were being included within the landscape unit boundary. In other words, though the actual total number of distinct units may have increased with increasing landscape unit size, the number increased at a much lower rate because more repetitive sites were being encountered.

The second null hypothesis was that: the number of sites per dominant distinct unit was independent of landscape unit size. The

## TABLE 152. COMPARISON OF DOMINANT DISTINCT UNITS

| Distinct Unit | | | Landscape Unit | | Percent of Landscape Unit Area |
|---|---|---|---|---|---|
| Slope* | Vegetation* | Geology* | | | |
| < 5 | 5-Dale-QUER-Rhtr-Yuel | Qc | 20 | | 21 |
| < 5 | 5-Dale-QUER-Rhtr-Yuel | Qc | 21 | * * | 63 |
| < 5 | 5-Dale-QUER-Rhtr-Yuel | Qc | 23 | | 71 |
| < 5 | 9-PJ-Matr-Yuba-Cebr | Ml | 46 | | 11 |
| < 5 | 11-Latr-Atca-GUTI-Lemo | Qc-fl | 50 | | 96 |
| < 5 | 11-Latr-Flce-Prju-Krgl | Qc-fl | 52 | | 6 |
| < 5 | 11-Latr-Prju-Acco-Pain | Qc-fl | 52 | | 6 |
| < 5 | 11-Latr-Prju-Flce-Vist | Qc-fl | 7 | | 6 |
| < 5 | 11-Latr-Prju-Krgl-Vist | Qc-fl | 52 | | 10 |
| < 5 | 11-Latr-Prju-Pain-Krgl | Qc-fl | 10 | | 30 |
| < 5 | 11-Latr-Vist-Prju-Pain | Qc-fl | 7 | | 7 |
| < 5 | 16-Vist-Latr-Atca-Prju | Qc-fl | 10 | | 30 |
| < 5 | 16-Vist-Latr-Atca-Prju | Qc-fl | 11 | * * | 97 |
| < 5 | 16-Vist-Latr-Atca-Prju | Qc-fl | 95 | | 61 |
| < 5 | 16-Yuto-Vist-Latr-Coer | Qc-fl | 7 | | 4 |
| 5-50 | 16-Jupi-Dale-Vist-Mibi | Tl | 28 | * * | 82 |
| 5-50 | 16-Jupi-Dale-Vist-Mibi | Tl | 30 | | 59 |
| 5-50 | 16-Jupi-Dale-Vist-Mibi | Tl | 29 | | 40 |
| 5-50 | 5-Dale-QUER-Rhtr-Yuel | Qc | 20 | | 36 |
| 5-50 | 16-Jupi-QUER-Dale-Mibi | Tl | 29 | | 26 |
| 5-50 | 3-GUTI-Matr-Opim-Cebr | Ml | 42 | | 15 |
| 5-50 | 5-Cebr-Cegr-Dale-QUER | Ml | 15 | | 10 |
| 5-50 | 5-Dale-Note-Cebr-Dafo | Ml | 12 | | 1 |
| 5-50 | 5-Dale-Note-Mosc-Cebr | Ml | 12 | | 1 |
| 5-50 | 5-Mosc-Fosp-2-Cebr-Dafo | Ml | 12 | | 2 |
| 5-50 | 5-Note-Cebr-Cegr-Mosc | Ml | 45 | | 27 |
| 5-50 | 5-Note-Dale-Cebr-Mosc | Ml | 47 | | 29 |
| 5-50 | 5-PJ-Note-Dale-Cebr | Ml | 41 | | 26 |
| 5-50 | 5-PJ-Note-Dale-Cebr | Ml | 46 | | 24 |
| 5-50 | 5-PJ-QUER-Matr-Opim | Ml | 38 | | 25 |

TABLE 152 (Continued)

| Distinct Unit | | | Landscape Unit | Percent of Landscape Unit Area |
|---|---|---|---|---|
| Slope* | Vegetation* | Geology* | | |
| 5-50 | 6-PP-Psme-Acgr-PJ | M1 | 16 | 4 |
| 5-50 | 6-PP-Psme-Acgr-QUER | M1 | 16 | 8 |
| 5-50 | 9-PJ-Matr-Yuba-Cebr | M1 | 46 | 23 |
| 5-50 | 9-PJ-PP-Note-QUER | M1 | 44 | 14 |
| 5-50 | 10-Acgr-PP-Psme-Arte | M1 | 27 | 45 |
| 5-50 | 11-Latr-Vist-Prju-Pain | M1 | 9 | 98 |
| 5-50 | 16-Dale-Pain-Dafo-Vist | M1 | 12 | 1 |
| 5-50 | 16-Dale-Vist-Pain-Dafo | M1 | 12 | 2 |
| 5-50 | 16-Dale-Vist-Pain-Fosp-1 | M1 | 12 | 1 |
| 5-50 | 16-Vist-Latr-Pain-Dale | M1 | 12 | 2 |
| 5-50 | 16-Yuto-Vist-Latr-Coer | M1 | 8 | 34 |
| 5-50 | 5-JUNI-QUER-Arte-Mibi | Qc | 57 | 4 |
| 5-50 | 11-Latr-Mosc-Vist-Coer | Qc | 52 | 15 |
| 5-50 | 11-Latr-Pain-Prju-Daar | Qc | 12 | 1 |
| 5-50 | 16-Jupi-Dale-QUER-Mibi | Qc | 4 | 45 |
| 5-50 | 3-GUTI-Opim-Rhmi-DafO | Qc-f1 | 57 | 10 |
| 5-50 | 5-Note-Cebr-Dale-QUER | Qc-f1 | 42 | 16 |
| 5-50 | 11-Latr-Flce-Prju-Krgl | Qc-f1 | 52 | 7 |
| 5-50 | 11-Latr-Krgl-Coer-Pain | Qc-f1 | 52 | 6 |
| 5-50 | 11-Latr-Prju-Daar-Krgl | Qc-f1 | 57 | 6 |
| 5-50 | 11-Latr-Prju-Flce-Vist | Qc-f1 | 51 | 6 |
| 5-50 | 11-Latr-Prju-Krgl-Pain | Qc-f1 | 7 | 3 |
| 5-50 | 11-Latr-Prju-Pain-Dafo | Qc-f1 | 7 | 5 |
| 5-50 | 11-Latr-Prju-Pain-Dafo | Qc-f1 | 57 | 6 |
| 5-50 | 11-Latr-Vist-Prju-Pain | Qc-f1 | 7 | 11 |
| 5-50 | 16-Vist-Latr-Coer-Krgl | Qc-f1 | 7 | 3 |
| 5-50 | 16-Yuto-Vist-Latr-Coer | Qc-f1 | 7 | 9 |
| 5-50 | 16-Vist-Latr-Pain-Dale | Sh | 12 | 1 |
| 5-50 | 3-GUTI-Opim-Rhmi-Dafo | SS | 57 | 5 |

TABLE 152 (Continued)

| Distinct Unit | | | Landscape Unit | Percent of Landscape Unit Area |
|---|---|---|---|---|
| Slope* | Vegetation* | Geology* | | |
| 5-50 | 3-GUTI-Opim-Rhmi-Dafo | SS | 58 | 22 |
| 5-50 | 11-Latr-Pain-Prju-Daar | SS | 53 | 16 |
| 5-50 | 11-Latr-Vist-Pain-OPPP | SS | 53 | 11 |
| 5-50 | 16-Dale-Vist-Pain-Cebr | SS | 54 | 12 |
| 5-50 | 16-Dale-Vist-Pain-Cebr | SS | 58 | 20 |
| 5-50 | 16-Dale-Vist-Pain-Mibi | SS | 5 | 5 |
| 5-50 | 16-Jupi-Dale-QUER-Mibi | SS | 4 | 12 |
| 5-50 | 16-Jupi-QUER-Dale-Mibi | SS | 27 | 12 |
| 5-50 | 16-Pain-Acco-Opim-Vist | SS | 54 | 5 |
| 5-50 | 5-Dale-Vist-QUER-Cebr | SL | 5 | 6 |
| 5-50 | 5-Jupi-QUER-Rhtr-Mibi | SL | 5 | 4 |
| 5-50 | 16-Dale-Vist-Latr-Pain | SL | 57 | 4 |
| 5-50 | 16-Dale-Vist-Pain-Mibi | SL | 5 | 10 |
| 5-50 | 1-Opim-Prju-Vist-Rhtr | T1 | 58 | 16 |
| 5-50 | 3-GUTI-Matr-Opim-Cebr | T1 | 42 | 33 |
| 5-50 | 5-Dale-Note-QUER-Cebr | T1 | 39 | 8 |
| 5-50 | 5-Note-Cebr-Cegr-Mosc | T1 | 45 | 27 |
| 5-50 | 5-Note-Cebr-Dale-QUER | T1 | 40 | 20 |
| 5-50 | 5-Note-Cebr-Dale-QUER | T1 | 43 | 35 |
| 5-50 | 5-Note-ROSA-QUER-Cebr | T1 | 39 | 6 |
| 5-50 | 5-PJ-Note-Dale-Cebr | T1 | 41 | 42 |
| 5-50 | 5-PJ-QUER-Matr-Opim | T1 | 38 | 14 |
| 5-50 | 5-QUER-Note-ROSA-Cebr | T1 | 39 | 13 |
| 5-50 | 6-PP-PJ-QUER-Cebr | T1 | 36 | 9 |
| 5-50 | 6-PP-PJ-QUER-Note | T1 | 36 | 6 |
| 5-50 | 6-PP-Psme-Acgr-PJ | T1 | 16 | 8 |
| 5-50 | 6-PP-Psme-Acgr-QUER | T1 | 16 | 13 |
| 5-50 | 6-PP-Psme-Acgr-QUER | T1 | 36 | 10 |
| 5-50 | 9-PJ-PP-Note-QUER | T1 | 44 | 41 |
| 5-50 | 11-Latr-Vist-Pain-Daar | T1 | 12 | 3 |

TABLE 152 (Continued)

| Distinct Unit | | | Landscape Unit | Percent of Landscape Unit Area |
|---|---|---|---|---|
| Slope* | Vegetation* | Geology* | | |
| 5-50 | 16-Dale-Vist-Pain-Mibi | T1 | 5 | 8 |
| 5-50 | 16-Yuto-Vist-Latr-Coer | T1 | 8 | 31 |
| > 50 | 5-Cebr-Cegr-Dale-QUER | M1 | 15 | 40 |
| > 50 | 5-Cebr-Cegr-QUER-Dale | M1 | 14 | 23 |
| > 50 | 5-Cebr-Cegr-QUER-Dale | M1 | 16 | 8 |
| > 50 | 5-Cebr-Dale-Pain-Cegr | M1 | 22 | 59 |
| > 50 | 5-Cebr-Dale-Pain-Cegr | M1 | 54 | 15 |
| > 50 | 5-Cebr-QUER-Cegr-Dale | M1 | 12 | 1 |
| > 50 | 5-Cebr-QUER-Cegr-Dale | M1 | 13 | 33 |
| > 50 | 5-Dale-Note-Cebr-Dafo | M1 | 12 | 3 |
| > 50 | 5-Dale-Note-Mosc-Cebr | M1 | 12 | 1 |
| > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | 2 | 24 |
| > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | 3 | 15 |
| > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | 6 | 72 |
| > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | 17 | 15 |
| > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | 32 | 18 |
| > 50 | 5-Dale-QUER-Cebr-Cegr | M1 | 3 | 14 |
| > 50 | 5-Dale-QUER-Cebr-Mibi | M1 | 3 | 14 |
| > 50 | 5-Dale-QUER-Cebr-Note | M1 | 3 | 6 |
| > 50 | 5-Dale-QUER-Cebr-Vist | M1 | 34 | 61 |
| > 50 | 5-Mosc-Fosp-2-Cebr-Dafo | M1 | 12 | 1 |
| > 50 | 5-Note-Dale-Cebr-Mosc | M1 | 12 | 2 |
| > 50 | 5-Note-Dale-Cebr-Mosc | M1 | 47 | 27 |
| > 50 | 5-QUER-Cebr-Cegr-Note | M1 | 17 | 26 |
| > 50 | 5-QUER-Dale-Cebr-Feru | M1 | 3 | 4 |
| > 50 | 6-PP-Acgr-Arte-QUER | M1 | 1 | 75 |
| > 50 | 6-PP-Acgr-Arte-QUER | M1 | 2 | 35 |
| > 50 | 6-PP-Acgr-Arte-QUER | M1 | 32 | 22 |
| > 50 | 6-PP-Acgr-Psme-QUER | M1 | 12 | 1 |
| > 50 | 6-PP-Acgr-Psme-QUER | M1 | 13 | 13 |

TABLE 152 (Continued)

| Distinct Unit | | | Landscape Unit | Percent of Landscape Unit Area |
|---|---|---|---|---|
| Slope* | Vegetation | Geology* | | |
| > 50 | 6-PP-Acgr-Psme-QUER | M1 | 14 | 40 |
| > 50 | 6-PP-Psme-Acgr-QUER | M1 | 16 | 8 |
| > 50 | 6-PP-Psme-Acgr-QUER | M1 | 32 | 23 |
| > 50 | 8-Rock | M1 | 12 | 2 |
| > 50 | 11-Latr-Vist-Prju-Pain | M1 | 57 | 5 |
| > 50 | 16-Agle-Pain-Vist-Dafo | M1 | 51 | 12 |
| > 50 | 16-Dale-Fosp-1-Pain-Chdu | M1 | 12 | 2 |
| > 50 | 16-Dale-Vist-Pain-Dafo | M1 | 12 | 2 |
| > 50 | 16-Dale-Vist-Pain-Fosp-1 | M1 | 12 | 4 |
| > 50 | 16-Dale-Vist-Pain-Fosp-1 | M1 | 57 | 6 |
| > 50 | 16-Fosp-1-Agle-Vist-Pain | M1 | 57 | 3 |
| > 50 | 16-Pain-Vist-Agle-Latr | M1 | 51 | 14 |
| > 50 | 16-Vist-Latr-Pain-Dale | M1 | 12 | 1 |
| > 50 | 11-Latr-Prju-Pain-Dafo | Qc-fl | 57 | 4 |
| > 50 | 16-Agle-Pain-Vist-Dafo | Qc-fl | 51 | 5 |
| > 50 | 5-Dale-Note-Cebr-Dafo | Sh | 12 | 1 |
| > 50 | 16-Dale-Vist-Pain-Fosp-1 | Sh | 12 | 1 |
| > 50 | 5-Cebr-QUER-Cegr-Dale | SS | 13 | 11 |
| > 50 | 5-Dale-Note-Cebr-Dafo | SS | 12 | 1 |
| > 50 | 11-Latr-Pain-Prju-Daar | SS | 53 | 19 |
| > 50 | 11-Latr-Vist-Pain-OPPP | SS | 53 | 13 |
| > 50 | 16-Acco-Pain-Vist-Muse | SS | 54 | 4 |
| > 50 | 16-Dale-Fosp-2-Mosc-Cebr | SS | 12 | 2 |
| > 50 | 16-Dale-Vist-Pain-Fosp-1 | SS | 12 | 3 |
| > 50 | 16-Pain-Acco-Opim-Vist | SS | 54 | 7 |
| > 50 | 16-Vist-Latr-Pain-Dale | SS | 12 | 1 |
| > 50 | 16-Vist-Pain-Dale-Cebr | SS | 54 | 5 |
| > 50 | 5-Dale-Vist-QUER-Cebr | SL | 5 | 17 |
| > 50 | 5-Dale-Note-QUER-Cebr | T1 | 39 | 10 |
| > 50 | 5-Dale-QUER-Cebr-Note | T1 | 37 | 26 |

TABLE 152 (Continued)

| Distinct Unit | | | Landscape Unit | Percent of Landscape Unit Area |
|---|---|---|---|---|
| Slope* | Vegetation* | Geology* | | |
| > 50 | 5-Note-Cebr-Cegr-QUER | T1 | 43 | 12 |
| > 50 | 5-Note-Cebr-Dale-QUER | T1 | 40 | 38 |
| > 50 | 5-Note-Cebr-Dale-QUER | T1 | 43 | 7 |
| > 50 | 5-Note-Dale-Cebr-Mosc | T1 | 12 | 2 |
| > 50 | 5-Note-QUER-Cebr-Dale | T1 | 37 | 23 |
| > 50 | 5-QUER-Cebr-Cegr-Note | T1 | 17 | 10 |
| > 50 | 5-QUER-Cebr-Cegr-Note | T1 | 37 | 23 |
| > 50 | 5-QUER-Cebr-Cegr-Note | T1 | 38 | 18 |
| > 50 | 5-Note-QUER-Dale-Cebr | T1 | 36 | 5 |
| > 50 | 5-QUER-Note-ROSA-Cebr | T1 | 39 | 14 |
| > 50 | 6-PP-PJ-QUER-Cebr | T1 | 36 | 15 |
| > 50 | 6-PP-Psme-Acgr-PJ | T1 | 16 | 4 |
| > 50 | 6-PP-Psme-Acgr-QUER | T1 | 36 | 8 |
| > 50 | 9-PJ-Matr-Yuba-Cebr | T1 | 12 | 1 |
| > 50 | 16-Dale-Vist-Pain-Mibi | T1 | 5 | 4 |
| > 50 | 16-Vist-Pain-Dale-Cebr | T1 | 54 | 4 |

*Refer to Appendices K, L, and M for explanation of class terms.

**Brackets indicate those landscape unit pairs having single identical dominant distinct units.

test showed that the number of sites per dominant distinct unit was positively correlated to landscape unit area (r = 0.57). The null hypothesis was rejected and the alternative hypothesis of positive correlation was accepted. Since a positive correlation was obtained, then the implication was that sites which constituted dominant distinct units were repeating themselves more frequently as landscape unit area increased.

The third null hypothesis stated that: the ratio of the number of dominant distinct units to the total number of distinct units in a landscape unit was independent of landscape unit size. The correlation was negative (r = -0.75), thus the null hypothesis was rejected and the alternative hypothesis of negative correlation was accepted. This result implied that the number of dominant distinct units was remaining low, or increasing only slightly as landscape unit area increased. Hence, not only was site repetition becoming more frequent, it was becoming more frequent in the very restricted range of slope, vegetation and geology of the dominant distinct units.

In consequence the following conclusions were drawn: (1) that identical sites were recurring as landscape unit area increased; (2) that the repetitive sites were recurring frequently; and (3) that the frequent recurrence was particularly associated with the dominant distinct units.

These results would not occur in a series of randomly configured landscape units delineated on aerial photographs. As random units increased in size, they would certainly encompass a larger number of sites; however, site repetitiveness within such a unit would occur only by chance which should not have led to rejection of the established null hypotheses. Thus the contention that the landscape units do represent internally homogeneous areas with respect to the variables of interest, is supported by the ground truth data analysis.

To summarize, the results of this research indicate that the delineated landscape units are indeed unique and distinct entities which display a greater degree of internal homogeneity than would a series of randomly configured units of similar size.

## CONCLUSIONS

Attempts to divide the surface of the earth into areas or units which are internally homogeneous and distinct from adjacent areas, have been undertaken throughout recorded history. Such efforts are generally founded upon the recognition that if we are to use our lands in the best possible ways, it is necessary to develop some form of order or structure within the range of natural variety which surrounds us. There are numerous approaches which can be applied to a given area in order to classify the land into manageable units. These approaches vary with respect to their specific methodologies, as well as in terms of cost efficiency and data quality.

Unit delineation on the basis of photographic image tone, texture and pattern has been proposed as a viable technique for obtaining land classification entities in a timely and cost effective manner. However, previous work has been largely confined to relatively less complex areas, primarily lowlands or plains, and none of the studies was able to compare the delineated units on the basis of complete ground truth data for the variables of concern.

In managing for preservation and recreation or, indeed, any other kind of land management, the data which are used for analysis must meet two basic criteria. Initially the data must include those natural elements whose interactions are predominant in the area of interest. Not all data can be derived from one source, but aerial photography can provide much of it, and other elements or their effects can be inferred, e.g., climate and the presence or absence of water. The data must be detailed enough to provide adequate information for small or unique areas which will require intensive management. Concomitantly, the data should be able to provide information from which meaningful generalizations can be drawn. As a result, the data must be suitable for analysis.

The second basic requirement concerns the organization of the data. Natural elements do not occur in isolation; rather, they form associations whose effects are often more than the sum of the parts. Consequently, data organization should take this into account.

The land system concept accommodates the need for detailed information from which broader generalizations can be drawn as required and, at the same time, organizes the collection and analysis of data in such a way that the interrelationships of elements are recognized and preserved.

Some of the specific information which may be of use is presented in the following discussion. In terms of boundary delineations, it was found that photographic interpretation techniques distinguished fine differences in slope, vegetation and geology. Though further studies or management considerations may indicate that these fine distinctions can be ignored, it is well to note that those differences do exist and, since they might be important, that aerial photographic interpretation has shown its utility as a means to identify them. Similarly, the tests which showed the uniqueness of the landscape units were made at a very stringent level requiring 90 percent agreement among all three factors of slope, vegetation and geology. This could also be relaxed, but to reiterate, the stringent test provides a margin of safety in the event that future studies may show the differences to be of importance.

The concept of homogeneity is particularly important to management because it is this which can be used to guide the development of various practices. Homogeneity was found to involve the physical and biological composition of sites as well as the number of sites. In regard to the latter, it was noted that the sites exhibited repetitiveness and that the frequency of repetition was particularly associated with the dominant distinct units, those which made up 50 percent or more of a given landscape unit.

Site repetition is important because it may suggest the existence of catena or continuum relationships or, at least, significant associations. If an area has groups or associations of identical sites then a management practice can be developed on a broader scale, avoiding the necessity and virtual impossibility of individual site management. It would also indicate to some extent the diversity of a landscape unit and aid in determining how flexible or specific site management practices might have to be.

The management of a land area is concerned with many things, not the least of which is how much of the area is made up of the same or similar kinds of distinct units. If 50 percent or more of an area is made up of only a few distinct units, then management practices could be geared toward those few with the smaller areas identified and used as limiting factors. The smaller areas may be of critical importance in terms of how they respond to management practices, so it is important that they be included in the analysis.

This research effort has clearly shown that landscape units can be effectively delineated in a region of extreme diversity and complexity. The boundaries of the delineated units were examined and shown to be real in terms of slope, vegetative and geologic variables. The units were shown to be unique and to be internally homogeneous when compared to randomly configured units of similar size. In addition, it was found that each landscape unit was dominated by limited associations of slope, vegetation and geology. The recognition of dominant distinct units holds particular value for the application of the land system concept to rugged or remote areas. Provided that the landscape units were delineated with care, the necessity for complete ground truth is obviated; hence, only sampling would be required to obtain the necessary data for reliable extrapolation. Areas of particular or critical concern can also be readily identified and sampled more intensively as the situation demands.

Of particular interest and importance to the over-all objectives of the present research program is the applicability of landscape units in analysis of watershed similarities and their potential for supporting the transference of hydrologic information from intensive study watersheds to other drainages within the park.

To evaluate the information content of the traditional watershed inventory and description data (discussed in Chapter III) compared to the landscape unit analysis approach, a second similarity index was produced using only landscape composition.

A computer program was used to expedite the analysis and determination of similarity indices. The program compared each watershed, "base watershed" to all other watersheds in terms of their respective compositions or variable values. Comparisons were made on the basis of variable differences or deviations, expressed as a percent, of the compared watershed from the "base watershed." The deviations were then totaled for each watershed pair and divided by the number of variables being considered. The resulting index with values ranging from 0.0 to

1.0, then made it possible to determine which watersheds were similar in relation to all of the measured variables. An index value of 0.0 indicates the watersheds were identical while index values approaching 1.0 express an ever-decreasing similarity. The twenty most similar pairs of watersheds from each analysis (approximately three percent of all possible pairs) were then used to construct clusters of very highly similar watersheds.

The results of the watershed similarity analyses using landscape unit composition as the discriminating factor and assuming each landscape unit to be unique are presented in Table 153 and Figure 169.

Traditional analysis accounted for 19 watersheds and resulted in five clusters of highly similar watersheds (Table 154 and Figure 170). The analysis performed on the basis of landscape unit composition accounted for 14 watersheds and resulted in four clusters of highly similar watersheds. Comparing the "similar watershed" list and the clusters developed by the landscape unit approach to the more traditional approach the results seem very favorable.

1. Twelve of the twenty pairs on the landscape unit list were identical to the hydrologic variable pair list.
2. Seven of the eight "non-identical" pairs involved pair similarities within one of the established clusters and therefore did not affect the cluster group. The one remaining pair involved a watershed which had previously been unaccounted for by the hydrologic variable analysis.
3. There were no instances of cross clustering. Differences in cluster composition occurred only between a specific cluster and the pool of unaccounted for watersheds.

The time and effort involved to obtain the clusters of highly similar watersheds by means of the hydrologic variable analysis approach exceeded the landscape unit approach by a factor of ten. This reduction in analyses costs coupled with the favorable similarity of final results indicates a potential for increased use of the landscape unit analysis approach in natural resource management planning.

## TABLE 153. MOST SIMILAR WATERSHED PAIRS--LANDSCAPE UNITS

| Watershed Pair | Index Value |
|---|---|
| 10A3-10A4 | 0.0100 |
| 5A1-7 | 0.0900 |
| 10A4-10B1 | 0.0900 |
| 10A3-10B1 | 0.0900 |
| 10A2-10A3 | 0.1000 |
| 10A2-10A4 | 0.1000 |
| 10A2-10B1 | 0.1400 |
| 10A6-10B1 | 0.1500 |
| 10A3-10A6 | 0.1600 |
| 10A4-10A6 | 0.1600 |
| 10A1-10A3 | 0.1700 |
| 10B2-10B6 | 0.1800 |
| 10B4-10B5 | 0.1800 |
| 10A1-10A4 | 0.1800 |
| 10B1-10B4 | 0.1900 |
| 10A2-10A6 | 0.2000 |
| 10A2-10B4 | 0.2000 |
| 10A3-10B4 | 0.2000 |
| 10A4-10B4 | 0.2000 |
| 8B-8D | 0.2200 |

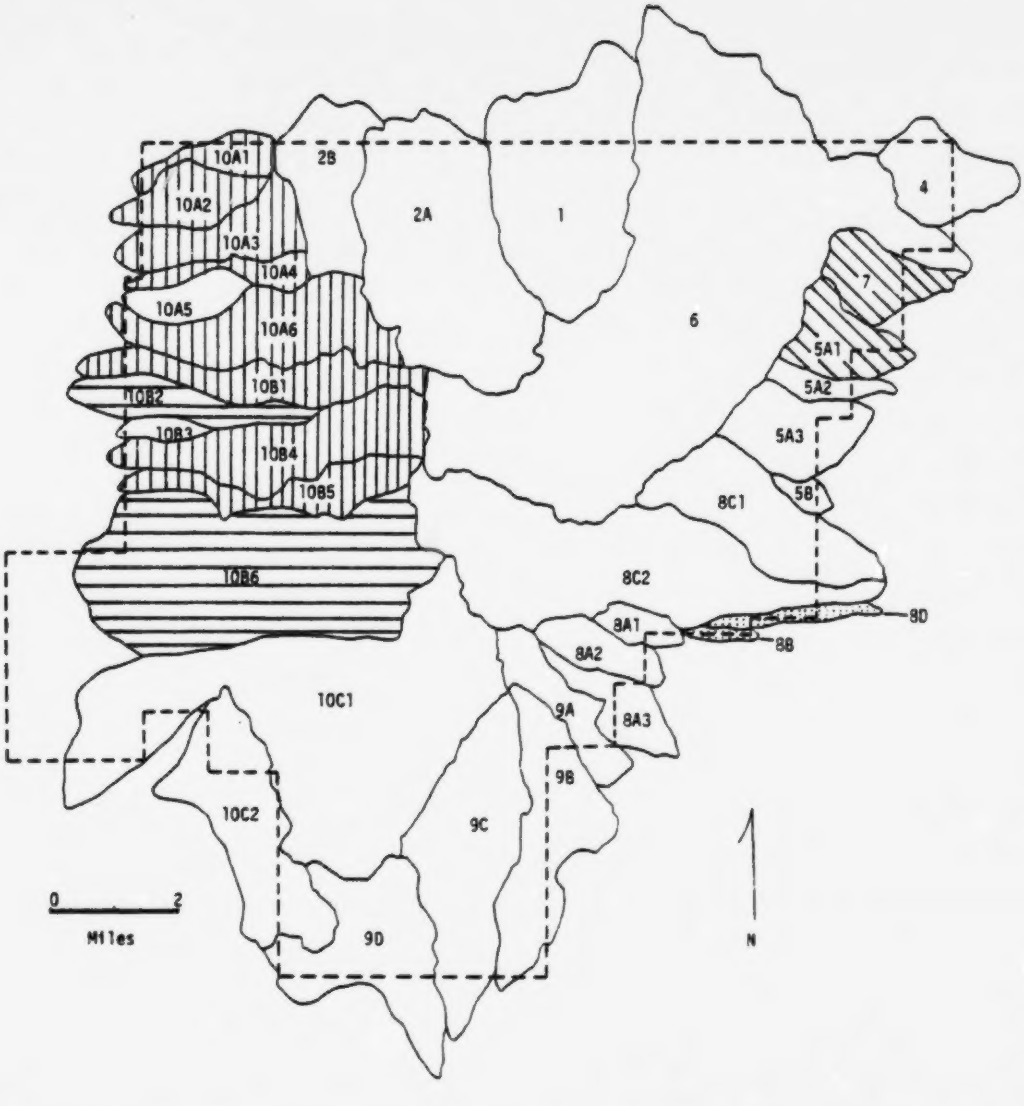

Figure 169. Watershed Clusters -- Landscape Unit Approach.

## TABLE 154. MOST SIMILAR WATERSHED PAIRS--HYDROLOGIC VARIABLES

| Watershed Pair | Index Value |
|---|---|
| 4-7 | 0.1385 |
| 10A3-10A4 | 0.1464 |
| 10A6-10B4 | 0.1568 |
| 10A2-10A5 | 0.1663 |
| 10B1-10B5 | 0.1691 |
| 5A1-5A2 | 0.1702 |
| 5A1-7 | 0.1770 |
| 10A2-10A3 | 0.1861 |
| 10A6-10B1 | 0.1916 |
| 10A1-10A4 | 0.1964 |
| 10B4-10B5 | 0.2019 |
| 10B1-10B4 | 0.2030 |
| 10A3-10A6 | 0.2103 |
| 9B-9C | 0.2124 |
| 10A1-10A3 | 0.2211 |
| 10A2-10A4 | 0.2211 |
| 10A1-10A2 | 0.2233 |
| 10A3-10B1 | 0.2237 |
| 10B6-10C1 | 0.2332 |
| 8B-8D | 0.2377 |

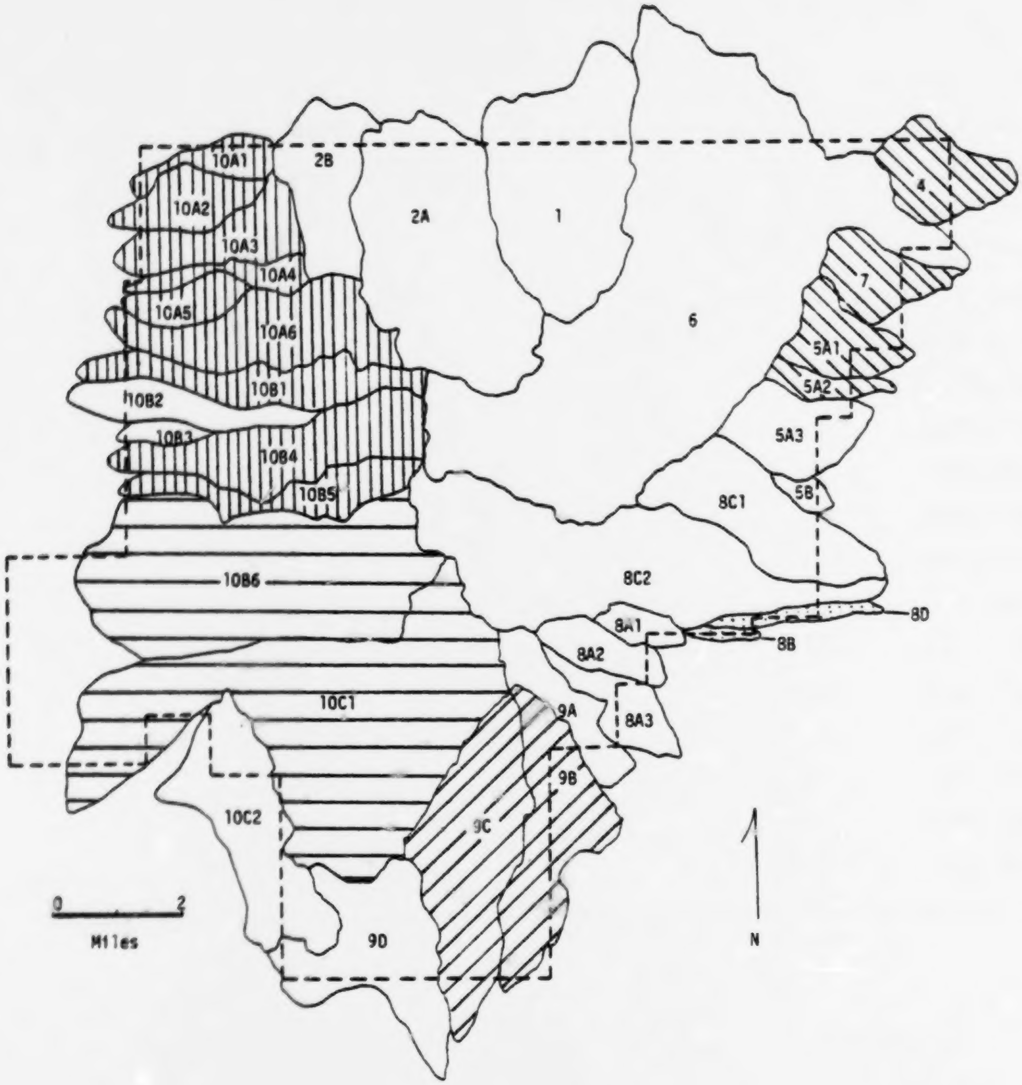

Figure 170. Watershed Clusters -- Hydrologic Variable Approach.

# CHAPTER XI RECOMMENDATIONS

The rapid increase in the Southwest's population is brought about by people's desire to live in the healthy and pleasant environment of the Southwest. We believe that diligent management of the region's finite natural resources is essential to assure that this quality of living and environment will be maintained. Further, we believe that the basis for a management program which will successfully achieve these goals is a complete understanding of the complex functional relationships which comprise the natural systems of the managed area. Traditionally these systems have been studied from an individual discipline viewpoint eg. forestry, range management, hydrology, recreation management and etc. Each of these individual disciplines while certainly complex in their own right generally fails to address the management of an area's resources from a holistic viewpoint which is essential if we are to achieve a totally comprehensive management program.

Our present research program has been a unique opportunity to begin just such an interdisciplinary or holistic study on the effects of recreational development in Guadalupe Mountains National Park. Final and conclusive recommendations concerning management programs which will achieve the goal of providing quality recreational experiences for today's population while preserving the park's resources for the enjoyment and use of future generations obviously cannot be achieved in the relatively short time span of the present study. However, we strongly believe that the present study has contributed significantly in two ways. First, and perhaps most importantly we have initiated the documentation of the current status of the park's resources. The research has established "benchmarks" which will provide data for scientists of the future to compare with the conditions they observe. Secondly the present research effort has provided an opportunity to observe and study the current dynamics of the park's natural resource systems in the context of present management efforts coupled with the current recreational use patterns. Based on these observations and studies, a number of recommendations are possible directed both at management program formulation and at the necessity for the continuation of efforts which will enhance a more complete understanding of the functional interactions of the resource systems.

As discussed in Chapter II, the ability to manage natural resources implies a concept of carrying capacity. Central to this concept is the notion of a quantifiable definition of the intensity and type of usage which can be sustained over long periods of time under a given set of developmental and environmental circumstances. Establishment of viable carrying capacities is not a simple task and more often than not several iterations are required over a period of years before a reasonably sound value can be fixed for a particular situation. Current management programs in the park are primarily focusing on type of use as the mechanism to establish carrying capacity limits. While we believe that this strategy has been generally effective so far, with the rapidly expanding demand for all types of recreational experiences there now exists a need to begin to quantitatively define the amount of use in various type of use categories. Efforts to establish appropriate values should consider not only the biophysical impacts on the resource systems but should also involve the sociological carrying capacity aspects which affect the quality of various recreational experiences.

The results of this research indicate for example that many of the soils found in the park are highly susceptible to accelerated erosion, if the vegetative cover is adversely impacted by man's activities. These results should be considerations in the design criteria for trails and other facilities as well as providing a basis for the evaluation of the intensity of impact associated with various types and levels of use.

Another series of concerns are raised by the results of the water quality studies, particularly in the heavily used McKittrick Canyon area. A study should be undertaken to determine if the cesspool at the Pratt Lodge is a present source of pollution to the well and the stream. A tracer such as a fluorescent dye capable of detection at the 0.001 mg/l level could be added to the effluent at the cesspool. This tracer would then be monitored in the well water and in McKittrick Canyon Stream. The study should be run during the time of heaviest use of the cesspool, such as during the peak visitor use in late September and October.

The cesspool is an unsatisfactory on-site disposal system and is not approved of by the Texas Department of Health Resources. The system was originally designed to handle waste from only a few people, but as use of this area increases, the system eventually will be overloaded and will have to be re-designed. An on-site disposal system such as a septic tank with evapotranspiration beds may be feasible, but this will also require further investigation.

At the present no restroom facilities exist in South McKittrick Canyon. Visitors are, therefore, forced to resort to "natural restrooms." As use in this area of the park increases this may cause problems. Consideration must be given to designing a restroom and waste disposal system in South McKittrick, possibly at the Hunter Lodge picnic ground. Such a disposal system will help to alleviate the "natural restroom" problem.

Monitoring of water quality parameters should be a continuing effort throughout the park. Any natural or "artificial" damage to the watershed, such as damage to the vegetation, may cause a change in the water quality. A statement by Aldo Leopold (1941) reflects this concept:

> Soil and water are not two organic systems, but one. Both are organs of a single landscape; a derangement in either affects the health of both . . .

Direct measurements of surface hydrology phenomena data are visibly lacking in this report and to a degree expected. The occurrence of any surface hydrology phenomena in this area requires significant precipitation and the relatively short duration of the study did not result in sufficient precipitation phenomena to insure the occurrence of any significant surface runoff. Further constraints were present in that permanent gaging locations could not be installed. Observation of runoff phenomena required physical measurement during the occurrence of the actual event (i.e. personnel were required on the sites of concern). Since distance and availability of personnel were not always compatible with precipitation events no actual on site physical measurement of runoff is reported.

Data included in this report will make future assessment of runoff production and phenomena easier in that most physical characteristics of the selected watersheds are documented. Future assessment of runoff will be able to use the documented characteristics plus actual observations to make reasonably accurate estimates of runoff.

The runoff producing characteristics of the watershed tend to support expected large runoff rates and volumes. The steepness, geology, and drainage nets inherent within the watersheds are all supportive of this fact and must be considered in developmental plans for the park. Accelerated erosion is a definite possibility particularly if park development results in establishment of possible drainage water courses such as trails and roads. These could well become significant additional tributaries to the existing drainage nets resulting in decreased times of concentration and commensurate runoff rate increases.

Since there is some historical evidence of extremely high runoff rates and levels as well as predictions for soil type flows, precautions should be taken to avoid permanent developments (camp sites, visitor centers, etc.) in the flood plains of the major streams and in narrow canyons. The watersheds are very responsive to the convective type of storms prevalent within the park thus runoff occurrences can be not only of high velocity and rate but also sudden in their occurrence. This, if not properly recognized as a potential phenomena, could result in a danger to park inhabitants/users. Additionally the physical damages to structures, facilities, etc. if not properly located could be significant.

The runoff predictions reported were based upon two commonly accepted methods - the rational method and the Soil Conservation Service (SCS) method. Both methods possess advantages and disadvantages for the nature of the park but are considered to be reasonably valid. Since "hard" data was lacking to the extent necessary to provide specific predictions and verification thereof, a broad range of predictions were presented. Continued monitoring of the phenomena/characteristics should result in refinement of predictions and the establishment of explicit predictive relationships for runoff phenomena. It is felt that sufficient baseline and physical watershed characteristic data is included to provide planners with initial criteria for proper design of developments in the park.

We believe that water quality parameters, and indicators of accelerated erosion, will be the most sensitive indicators of adverse impacts in this semi-arid environment and strongly recommend that they be closely and continually observed as a part of the on going management program of the park. This research effort has established a solid foundation for such activities in the intensively studied watersheds and has indicated how these results may be extrapolated to other similar watersheds within the park. The current research has also produced information which should have value on a wider basis to other recreational use situations in similar semi-arid environments throughout the southwestern United States.

In anticipation of the conclusion of the present research program a "Phase II" project proposal was prepared and submitted to the Office of Water Research and Technology. The primary focus of this proposal is to continue the meterological, water quality, erosion and surface hydrology monitoring activities initiated under the current research program so as to provide an expanded basis for natural resource system management decision making in Guadalupe Mountains National Park, Texas.

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APPENDIX A--ANNUAL BACKCOUNTRY USE IMPACTING STUDY WATERSHEDS.

Total Visits

| Trail | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|
| Pine Canyon | 3,484 | 4,563 | 4,672 | 4,152 |
| Bear Canyon | 1,546 | 1,226 | 1,309 | 1,097 |
| Bowl | 128 | 672 | 960 | 962 |
| McKittrick Canyon | 3,719 | 5,006 | 8,861 | 12,269 |
| North McKittrick | 22 | 62 | 117 | 115 |

Backpacking User Days

| Trail | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|
| Pine Canyon | 3,319 | 2,258 | 2,798 | 2,738 |
| Bear Canyon | 563 | 808 | 969 | 910 |
| Bowl | -- | -- | -- | -- |
| McKittrick Canyon | 301 | 670 | 1,246 | 793 |
| North McKittrick | 13 | 50 | 87 | 78 |
| Totals | 4,196 | 3,786 | 5,200 | 4,519 |

Day Hiking User Days

| Trail | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|
| Pine Canyon | 1,757 | 2,528 | 2,510 | 1,805 |
| Bear Canyon | 468 | 498 | 560 | 317 |
| Bowl | 128 | 672 | 960 | 962 |
| McKittrick Canyon | 3,348 | 4,402 | 7,821 | 11,629 |
| North McKittrick | 17 | 82 | 50 | 49 |
| Totals | 5,718 | 8,182 | 11,901 | 14,762 |

## Total User Days

| Trail | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|
| Pine Canyon | 5,076 | 4,786 | 5,308 | 4,543 |
| Bear Canyon | 1,031 | 1,306 | 1,529 | 1,227 |
| Bowl | 128 | 672 | 960 | 962 |
| McKittrick Canyon | 3,649 | 5,072 | 9,167 | 12,422 |
| North McKittrick | 30 | 132 | 137 | 127 |
| Totals | 9,914 | 11,968 | 17,101 | 19,281 |

## Overnight Stays

| Watershed | Camp | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|
| 6 | Pine Top | 942 | 1,103 | 1,254 | 1,162 |
| 6 | Bush Mountain | 373 | 341 | 398 | 309 |
| 6 | Blue Ridge | 194 | 145 | 180 | 223 |
| 6 | McKittrick Ridge | 332 | 507 | 678 | 461 |
| 1 | Dog Canyon | 124 | 121 | 174 | 245 |
|  | Totals | 1,965 | 2,217 | 2,684 | 2,400 |

# APPENDIX B--SOIL PROFILE DESCRIPTIONS.

## 1S

Location: Approximately 21 km (13 miles) east of Dell City, Texas on pipeline road at base of Guadalupe escarpment on western side of park, then up Bean Burner Canyon approximately 1.6 km (1 mile).

Site: Mountain upland

Slope: 30%

Aspect: SSW

Parent Material: Thin talus mantle overlying limestone bedrock.

Vegetation: *Yucca* spp.; Skeletonleaf goldeneye (*Viguiera stenoloba*); ocotillo (*Fouquiera splendens*); Ephedra (*Ephedra trifurca*); *Opuntia* spp.; black grama (*Bouteloua eriopoda*).

| Horizon | cm | |
|---|---|---|
| A1 | 0-11 | Dark brown (10YR 4/3) gravelly loam; weak platy and weak subangular blocky; slightly hard, firm; many fine roots; few small limestone fragments; violently calcareous; clear smooth boundary. |
| B1ca | 11-32 | Dark yellowish brown (10YR 4/4) very cobbly loam, weak granular; soft, friable; many fine roots; limestone cobbles comprise 50% by volume; violently calcareous; clear wavy boundary. |
| B2ca | 32-56 | Yellowish brown (10YR 5/4) very gravelly loam; weak subangular blocky; soft, firm; common fine and medium roots; limestone fragments comprise 50% by volume; violently calcareous; clear wavy boundary. |

| | | |
|---|---|---|
| B3ca | 56-65 | Yellowish brown (10YR 5/4) very gravelly loam; rock controlled; soft, friable; few fine and medium roots; limestone fragments larger than in upper horizons; violently calcareous; clear irregular boundary. |
| Rca | 65 + | Fragmented limestone bedrock; violently calcareous. |

## 1N

**Location**: Approximately 150 m directly across the canyon from site 1S on the north aspect.

**Site**: Mountain upland

**Slope**: 34%

**Aspect**: NNE

**Parent Material**: Thin talus mantle overlying limestone bedrock.

**Vegetation**: *Yucca* spp.; *Opuntia* spp.; Ephedra (*Ephedra trifurca*); broomweed (*Xanthocephalum dracunculoides*); sandpaper bush (*Mortonia scabrella*); *Senecio* spp.; sideoats grama (*Bouteloua curtipendula*).

| Horizon | cm | |
|---|---|---|
| A11 | 0-12 | Very dark grayish brown (10YR 3/2.5) loam; weak subangular blocky; soft, friable; many fine roots; strongly calcareous; clear wavy boundary. |
| A12 | 12-25 | Dark brown (10YR 3/3) gravelly loam; weak grandular; loose, friable; many fine roots; violently calcareous; clear wavy boundary. |
| B1ca | 25-44 | Dark yellowish brown (10YR 4/4) gravelly loam; weak granular and weak subangular blocky; soft, firm; many fine roots; limestone fragments comprise 45 percent by volume; violently calcareous; gradual wavy boundary. |
| B2ca | 41-78 | Brown (10 YR 5/3) gravelly loam; weak subangular blocky; soft, firm; common fine roots; limestone fragments comprise 60 percent by volume; violently calcareous; gradual smooth boundary. |
| B3ca | 78-100+ | Pale brown (10YR 6/3) gravelly loam; weak subangular blocky; soft, friable; few fine and medium |

roots; many large limestone fragments; violently calcareous.

### 2S

**Location**: Approximately 1.7 km (1.1 mile) south of McKittrick Canyon parking lot, 184 m (200 yards) west into an east flowing canyon.

**Site**: Mountain upland

**Slope**: 28%

**Aspect**: SW

**Parent Material**: Limestone

**Vegetation**: *Yucca* spp.; *Opuntia* spp.; skeleton leaf goldeneye (*Viquiera stenoloba*); whitethorn acacia (*Acacia neovernicosa*); black grama (*Bouteloua eriopoda*); sideoats grama (*Bouteloua curtipendula*); *Muhlenbergia* spp.; lecheghilla (*Agave lecheghilla*); Gambel oak (*Quercus gambelii*).

| Horizon | cm | |
|---|---|---|
| A11 | 0-8 | Very dark grayish brown (10YR 3/2) clay loam; weak granular and weak subangular blocky; friable; many fine roots; few small limestone fragments; strongly calcareous; clear smooth boundary. |
| A12 | 8-19 | Very dark brown (10YR 2/2) gravelly clay loam; moderate subangular blocky; friable; many fine roots; small limestone fragments comprise 30 to 50 percent by volume; strongly calcareous; clear wavy boundary. |
| B2ca | 19-31 | Dark brown (10YR 4/3) very gravelly silty clay loam; weak subangular blocky; friable; common fine roots; flaggy to smaller limestone fragments comprise 70 percent by volume; violently calcareous; gradual wavy boundary. |
| B31ca | 31-46 | Dark brown (7.5YR 4/4) very gravelly silt loam; rock controlled; very friable; common fine roots; limestone fragments comprise 65 percent by volume with secondary $CaCO_3$ coatings; violently calcareous; gradual wavy boundary. |

| | | |
|---|---|---|
| B32ca | 46-62 | Strong brown (7.5YR 5/6) very gravelly silt loam; rock controlled; very friable; common fine roots; limestone fragments with secondary $CaCO_3$ coatings comprise 50 to 60 percent by volume; violently calcareous; abrupt wavy boundary. |

### 2N

Location: Approximately 150 m across from site 2S on north aspect.

Site: Mountain upland

Slope: 23%

Aspect: NE

Parent Material: Limestone, mixed residuum and colluvium.

Vegetation: Skunkbush (*Rhus aromatica*); Gambel oak (*Quercus gambelii*); whitethorn acacia (*Acacia neovernicosa*); smallseed sacahuista (*Nolina micrantha*); *Opuntia* spp.; New Mexico agave (*Agave neomexicana*); smooth sotol (*Dasylirion leiophyllum*); *Muhlenbergia* spp.; mountain mahogany (*Cercocarpus montanus* var. *paucidentatus*); Texas madrone (*Arbutus xalapensis*); alligator juniper (*Juniperus deppeana*); pinon pine (*Pinus edulis*).

| Horizon | cm | |
|---|---|---|
| O | 5-0 | Primarily oak leaves in various stages of decomposition. |
| A1 | 0-9 | Very dark brown (10YR 2/2) clay loam; moderate granular; friable; many fine and medium roots; noncalcareous; clear wavy boundary. |
| B1t | 9-19 | Dark brown (7.5YR 3/3) clay; moderate subangular blocky; firm; common medium roots; few small limestone fragments; noncalcareous; clear wavy boundary. |
| B21t | 19-34 | Dark brown (7.5YR 3/4) very gravelly clay; moderate subangular blocky; firm; common medium and coarse roots; 40 to 50 percent gravel and flaggy limestone fragments; very weakly calcareous; gradual wavy boundary. |
| B22t | 34-57 | Dark brown (7.5YR 3/4) very gravelly clay; rock controlled; firm; common medium and coarse roots; limestone fragments of various sizes comprise 50 |

| | | |
|---|---|---|
| | | percent by volume; weakly calcareous; gradual wavy boundary. |
| B3&R | 57-85 | Dark brown (7.5YR 3/3) very gravelly clay; rock controlled; friable; common medium and coarse roots; large limestone fragments comprise 60 percent by volume; secondary $CaCO_3$ coatings on limestone fragments; strongly calcareous; gradual wavy boundary. |
| Rca | 85+ | Fragmented limestone bedrock with secondary $CaCO_3$ filling fractures; common medium and coarse roots. |

## 3S

Location: Up Pine Canyon trail to top of escarpment the northeast approximately 1.6 km (1 mile) along trail toward the Bowl, then north for 140 meters (150 yards).

Site: Mountain upland

Slope: 26%

Aspect: SW

Parent Material: Fractured limestone and colluvium.

Vegetation: Gambel oak (*Quercus gambelii*); alligator juniper (*Juniperus deppeana*); pinon pine (*Pinus edulis*); *Muhlenbergia* spp., Indian ricegrass (*Oryzopsis hymenoides*); New Mexico agave (*Agave neomexicana*); *Opuntia* spp.; mountain mahogany (*Cercocarpus montanus* var. *paucidentatus*).

| Horizon | cm | |
|---|---|---|
| A11 | 0-9 | Very dark brown (10YR 2/2) clay loam; moderate fine granular; very friable; many fine and medium roots; limestone fragments comprise 10 percent by volume; noncalcareous; clear wavy boundary. |
| A12 | 9-21 | Very dark brown (10YR 2/2) clay loam; moderate mixed granular and subangular blocky; friable; many fine and medium roots; limestone fragments comprise 15 percent by volume; noncalcareous; clear wavy boundary. |
| B21&R | 21-38 | Very dark grayish brown (10YR 3/2) very gravelly clay loam; moderate subangular blocky; firm; many fine to medium roots; limestone fragments comprise |

| | | |
|---|---|---|
| | | 35 percent by volume; noncalcareous; clear irregular boundary. |
| B22t&R | 36-62 | Dark brown (7.5YR 3/4) very gravelly clay loam; rock controlled; firm; common medium roots; limestone fragments comprise 55 percent by volume; noncalcareus; clear irregular boundary. |
| B3t&R | 62-72 | Dark brown (7.5YR 3/4) clay; rock controlled; friable; common medium roots; limestone fragments comprise 50 to 60 percent by volume; weakly to moderately calcareous; clear irregular boundary. |
| Cca&R | 72-83+ | Very pale brown (10YR 7/3) clay; massive; moderately cemented; few medium roots; violently calcareous. |

### 3N

Location: Directly across from site 3S on opposite north-facing slope.

Site: Mountain upland

Slope: 25%

Aspect: NE

Parent Material: Limestone colluvium and bedrock.

Vegetation: Douglas fir (*Pseudotsuga menziesii*); alligator juniper (*Juniperus deppeana*); ponderosa pine (*Pinus ponderosa*); *Muhlenbergia* spp.; Gambel oak (*Quercus gambelii*).

| Horizona | cm | |
|---|---|---|
| O | 2-0 | Needles and grass in various stages of decomposition; abrupt smooth boundary. |
| A1 | 0-10 | Black (10YR 2/1) clay loam; moderate mixed granular and subangular blocky; friable; many fine and medium roots; few small limestone fragments; noncalcareous; clear wavy boundary. |
| B1t&R | 10-21 | Very dark brown (10YR 2/2) gravelly clay loam; moderate subangular blocky; firm; common fine and medium roots; large limestone fragments comprise 25 percent of volume; noncalcareous; clear irregular boundary. |

| | | |
|---|---|---|
| B21t&R | 21-38 | Dark brown (7.5YR 3/3) clay; moderate subangular blocky; firm; common, few medium and large roots; large limestone fragments comprise 15 percent of volume; weakly calcareous; gradual smooth boundary. |
| B22t&R | 36-60+ | Dark brown (7.5YR 3/4) clay; moderate subangular blocky; firm; common medium roots; large limestone fragments comprise 15 percent of volume and extend downward through horizon; weakly calcareous. |

# APPENDIX C--WATER QUALITY SAMPLING DATA.

## WATER QUALITY DATA FOR UPPER PINE SPRING

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/12/79 | 9.5 | 8.2 | 0.40 | 0.04 | 8.2 | -- | 9.0 | -- | -- | -- | -- | -- | -- | -- |
| 5/19/79 | 14.5 | 8.0 | 0.40 | 0.04 | 3.0 | 5.0 | 10.0 | 260 | 180 | -- | < 10 | < 5 | 599 | -- |
| 6/9/79 | 17.5 | 7.8 | 0.30 | 0.08 | 1.0 | 7.0 | -- | 270 | 185 | -- | < 10 | 7 | 737 | 1 |
| 7/25/79 | 19.0 | 7.2 | 0.15 | 0.04 | 19.0 | 2.0 | -- | 273 | 188 | 261 | 34 | 6 | 607 | 11 |
| Mean | 15.1 | 7.8 | 0.31 | 0.05 | 7.8 | 5.0 | 9.5 | 268 | 184 | -- | -- | -- | 648 | 6 |
| Maximum | 17.5 | 8.2 | 0.40 | 0.08 | 19.0 | 7.0 | 10.0 | 273 | 188 | 261 | 34 | 7 | 737 | 11 |
| Minimum | 9.5 | 7.2 | 0.15 | 0.04 | 1.0 | 2.0 | 9.0 | 260 | 180 | 261 | < 10 | < 5 | 599 | 1 |

## WATER QUALITY DATA FOR BONE SPRING

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/12/79 | 8 | 7.6 | 0.50 | 0.07 | 800 | -- | 8.6 | -- | -- | -- | -- | -- | -- | -- |
| 5/19/79 | 18 | 8.0 | 0.40 | 0.07 | 1,200 | 40 | 12.5 | 1,150 | 730 | -- | -- | -- | 2,518 | -- |
| 6/9/79 | 20 | 7.8 | -- | 0.04 | 1,000 | 38 | 8.5 | 1,065 | 550 | -- | < 10 | < 5 | 2,357 | 8 |
| 7/26/79 | 22 | 7.4 | 0.10 | 0.03 | 1,000 | 25 | -- | 993 | 520 | 223 | 19 | < 5 | 2,045 | 0 |
| Mean | 17 | 7.7 | 0.33 | 0.05 | 1,000 | 34 | 9.9 | 1,069 | 600 | -- | -- | -- | 2,307 | 4 |
| Maximum | 22 | 8.0 | 0.50 | 0.07 | 1,200 | 40 | 12.5 | 1,150 | 730 | 223 | 19 | < 5 | 2,518 | 8 |
| Minimum | 8 | 7.4 | 0.10 | 0.03 | 800 | 25 | 8.5 | 993 | 520 | 223 | < 10 | < 5 | 2,045 | 0 |

## WATER QUALITY DATA FOR SMITH SPRING

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/8/77 | -- | -- | 0.90 | 0.10 | 2.0 | -- | -- | 260 | 165 | -- | -- | -- | -- | -- |
| 10/5/77 | -- | -- | 0.60 | 0.00 | 2.0 | -- | -- | 250 | 165 | -- | -- | -- | -- | 0 |
| 11/22/78 | 13.5 | 7.9 | -- | 0.07 | 30.5 | -- | 8.3 | -- | -- | 267 | -- | -- | -- | -- |
| 1/12/79 | 11.0 | 8.0 | 0.07 | 0.02 | 7.0 | -- | 8.0 | -- | -- | -- | -- | -- | -- | -- |
| 2/6/79 | 11.0 | 7.4 | 0.30 | 0.06 | 5.0 | -- | 10.3 | -- | -- | -- | < 10 | -- | -- | -- |
| 3/21/79 | 14.0 | 7.6 | 0.20 | 0.05 | 18.0 | -- | 10.0 | 270 | 204 | -- | < 10 | < 5 | 275 | 0 |
| 5/18/79 | 16.0 | 8.0 | 0.40 | 0.60 | 3.0 | 2.5 | 9.0 | 280 | 200 | -- | < 10 | < 5 | 624 | -- |
| 6/9/79 | 16.0 | 7.5 | 0.20 | 0.07 | 1.0 | 7.0 | 10.5 | 290 | 185 | -- | 10 | 13 | 707 | 15 |
| 7/12/79 | 18.0 | 7.2 | 0.15 | 0.03 | 12.0 | 2.0 | -- | 265 | 200 | 275 | 15 | 11 | 601 | 100 |
| Mean | 14.2 | 7.7 | 0.35 | 0.11 | 8.9 | 3.8 | 9.4 | 269 | 186 | 271 | -- | -- | 552 | 29 |
| Maximum | 18.0 | 8.0 | 0.90 | 0.60 | 30.0 | 7.0 | 10.5 | 290 | 204 | 275 | 15 | 13 | 707 | 100 |
| Minimum | 11.0 | 7.2 | 0.15 | 0.00 | 1.0 | 2.0 | 8.0 | 260 | 165 | 261 | < 10 | < 5 | 275 | 0 |

## WATER QUALITY DATA FOR GUADALUPE SPRING

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/12/79 | 14 | 7.6 | 1.00 | 0.05 | 128 | -- | 6.8 | -- | -- | -- | -- | -- | -- | -- |
| 3/22/79 | 15 | 7.1 | 1.00 | 0.06 | 150 | -- | 13.0 | 360 | 230 | -- | < 10 | < 5 | 815 | 0 |
| 5/18/79 | 16 | 7.1 | 0.80 | 0.05 | 170 | 6.3 | 8.0 | 360 | 330 | -- | < 10 | < 5 | 844 | -- |
| 6/9/79 | 18 | 7.0 | 0.90 | 0.02 | 175 | 13.0 | -- | 375 | 290 | -- | < 10 | < 5 | 884 | 1 |
| 7/25/79 | 17 | 7.1 | 0.70 | 0.03 | 230 | 7.5 | -- | 385 | 250 | 231 | 14 | < 5 | 849 | 5 |
| Mean | 16 | 7.2 | 0.88 | 0.04 | 171 | 8.9 | 9.3 | 370 | 275 | -- | -- | -- | 848 | 2 |
| Maximum | 18 | 7.6 | 1.00 | 0.06 | 230 | 13.0 | 13.0 | 385 | 330 | 231 | 14 | < 5 | 884 | 5 |
| Minimum | 14 | 7.0 | 0.70 | 0.02 | 128 | 6.3 | 6.8 | 360 | 230 | 231 | < 10 | < 5 | 815 | 0 |

## WATER QUALITY DATA FOR MANZANITA SPRING

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/ cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/5/77 | -- | -- | 0.30 | 0.00 | 1.0 | -- | -- | 185 | 100 | -- | -- | -- | -- | 0 |
| 11/22/78 | 13.0 | 8.4 | -- | 1.30 | 21.2 | -- | -- | -- | -- | 245 | -- | -- | -- | -- |
| 1/12/79 | 7.0 | 8.3 | 0.40 | 0.08 | 2.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2/6/79 | 0.0 | 8.2 | 0.20 | 0.10 | 17.0 | -- | -- | -- | -- | -- | < 10 | -- | -- | -- |
| 3/21/79 | 15.0 | 8.2 | 0.20 | 0.06 | 26.0 | -- | -- | 230 | 148 | -- | < 10 | < 5 | 254 | -- |
| 5/18/79 | 17.5 | 8.1 | 0.20 | 0.08 | 16.0 | 4.5 | 8.5 | 220 | 170 | -- | < 10 | < 5 | 506 | -- |
| 6/9/79 | 28.0 | 8.2 | 0.10 | 0.05 | 14.0 | 6.0 | 18.5 | 190 | 90 | -- | < 10 | 16 | 412 | 2 |
| 7/25/79 | 30.0 | 7.2 | 0.11 | 0.04 | 3.0 | 2.0 | -- | 240 | 155 | 230 | 21 | < 5 | 483 | 63 |
| Mean | 15.8 | 8.1 | 0.22 | 0.21 | 12.6 | 4.2 | 13.5 | 213 | 133 | -- | -- | -- | 414 | 22 |
| Maximum | 30.0 | 8.4 | 0.40 | 1.30 | 21.2 | 6.0 | 18.5 | 240 | 170 | 230 | 21 | 16 | 506 | 63 |
| Minimum | 0.0 | 7.2 | 0.10 | 0.00 | 1.0 | 2.0 | 8.5 | 185 | 90 | 230 | < 10 | < 5 | 254 | 0 |

## WATER QUALITY DATA FOR FRIJOLE SPRING

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/ cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/8/77 | -- | -- | 0.90 | 0.10 | 10.0 | -- | -- | 240 | 150 | -- | -- | -- | -- | -- |
| 10/5/77 | -- | -- | 0.50 | 0.00 | 7.0 | -- | -- | 235 | 150 | -- | -- | -- | -- | 0 |
| 11/22/78 | 15.0 | 7.9 | -- | 0.06 | 30.5 | -- | 9.3 | -- | -- | 230 | -- | -- | -- | -- |
| 1/12/79 | 15.0 | 8.1 | 0.90 | 0.03 | 25.3 | -- | 6.4 | -- | -- | -- | -- | -- | -- | -- |
| 2/6/79 | 15.0 | 7.0 | 0.65 | 0.08 | 23.0 | -- | -- | -- | -- | -- | < 10 | -- | -- | -- |
| 3/21/79 | 17.0 | 7.2 | 0.30 | 0.05 | 17.0 | -- | 9.5 | 240 | 172 | -- | < 10 | < 5 | 266 | 0 |
| 5/18/79 | 16.5 | 7.1 | 0.50 | 0.08 | 20.0 | 5.0 | 8.0 | 270 | 180 | -- | < 10 | < 5 | 599 | -- |
| 6/9/79 | 17.0 | 7.2 | 0.50 | 0.04 | 19.0 | 9.0 | 9.0 | 265 | 170 | -- | < 10 | < 5 | 707 | 1 |
| 7/25/79 | 17.0 | 7.2 | 0.10 | 0.03 | 18.0 | 2.0 | -- | 270 | 180 | 254 | 14 | < 5 | 607 | 0 |
| Mean | 16.1 | 7.4 | 0.54 | 0.05 | 18.9 | 5.3 | 8.4 | 253 | 167 | 242 | -- | -- | 545 | < 1 |
| Maximum | 17.0 | 8.1 | 0.90 | 0.10 | 30.5 | 9.0 | 9.3 | 270 | 180 | 254 | 14 | < 5 | 707 | 1 |
| Minimum | 15.0 | 7.0 | 0.10 | 0.00 | 7.0 | 2.0 | 6.4 | 235 | 150 | 230 | < 10 | < 5 | 266 | 0 |

## WATER QUALITY DATA FOR CHOZA SPRING

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/8/77 | -- | -- | 0.50 | 0.10 | 8.0 | -- | -- | 210 | 110 | -- | -- | -- | -- | -- |
| 10/5/77 | -- | -- | 0.40 | 0.00 | 6.0 | -- | -- | 185 | 100 | -- | -- | -- | -- | -- |
| 11/22/78 | 14.0 | 8.6 | -- | -- | -- | -- | -- | -- | -- | 258 | -- | -- | -- | -- |
| 1/12/79 | 6.0 | 8.4 | 0.90 | 0.09 | 25.2 | -- | 9.9 | -- | -- | -- | -- | -- | -- | -- |
| 2/2/79 | 5.0 | 7.6 | 0.60 | 0.07 | 25.0 | -- | 14.5 | -- | -- | -- | < 10 | -- | -- | -- |
| 3/21/79 | 17.5 | 8.1 | 0.50 | 0.06 | 36.0 | -- | 9.5 | 270 | 180 | -- | < 10 | < 5 | 287 | 0 |
| 5/19/79 | 25.0 | 8.2 | 0.30 | 0.05 | 18.0 | 5.0 | 8.2 | 290 | 200 | -- | < 10 | < 5 | 613 | -- |
| 6/9/79 | 25.5 | 7.9 | 0.30 | 0.04 | 15.0 | 11.0 | 10.5 | 265 | 195 | -- | < 10 | 8 | 633 | 107 |
| 7/25/79 | 30.0 | 7.3 | 0.10 | 0.03 | 14.0 | 2.0 | -- | 265 | 170 | 245 | 24 | 10 | 595 | 119 |
| Mean | 17.6 | 8.0 | 0.45 | 0.06 | 18.4 | 6.0 | 10.5 | 248 | 159 | 252 | -- | -- | 532 | 75 |
| Maximum | 30.0 | 8.6 | 0.90 | 0.10 | 36.0 | 11.0 | 14.5 | 290 | 200 | 258 | 24 | 10 | 633 | 119 |
| Minimum | 5.0 | 7.3 | 0.10 | 0.00 | 6.0 | 2.0 | 8.2 | 185 | 100 | 245 | < 10 | < 5 | 287 | 0 |

## WATER QUALITY DATA FOR UPPER DOG CANYON SPRING

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/8/77 | -- | -- | 1.00 | 0.10 | 4.0 | -- | -- | 50 | 20 | -- | -- | -- | -- | -- |
| 2/3/79 | 6.0 | 8.0 | 0.60 | 0.09 | 30.0 | -- | 10.2 | -- | -- | -- | < 10 | -- | -- | -- |
| 5/20/79 | 12.0 | 7.8 | 0.30 | 0.40 | 18.0 | 5.0 | 9.5 | 320 | 200 | -- | < 10 | < 5 | 766 | -- |
| 6/7/79 | 14.4 | -- | 0.20 | 0.01 | 20.0 | 7.5 | -- | 320 | 165 | -- | < 10 | 7 | 589 | -- |
| 7/25/79 | 15.0 | 7.4 | 0.40 | 0.04 | 18.0 | 3.0 | -- | 325 | 175 | 303 | 36 | < 5 | 706 | 0 |
| Mean | 11.9 | 7.7 | 0.50 | 0.13 | 18.0 | 5.2 | 9.9 | 253 | 140 | -- | -- | -- | 687 | -- |
| Maximum | 15.0 | 8.0 | 1.00 | 0.40 | 30.0 | 7.5 | 10.2 | 325 | 200 | 303 | 36 | 7 | 766 | 0 |
| Minimum | 6.0 | 7.4 | 0.20 | 0.01 | 4.0 | 3.0 | 9.5 | 50 | 20 | 303 | < 10 | < 5 | 589 | 0 |

## WATER QUALITY DATA FOR SOUTH McKITTRICK SAMPLE SITE #1

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/27/79 | 15.0 | 8.0 | 0.10 | 0.03 | 14.0 | 2.5 | 9.0 | 220 | 145 | 225 | < 10 | 6 | 633 | -- |
| 6/22/79 | 23.0 | 7.1 | -- | 0.02 | 15.0 | -- | 9.0 | 235 | 128 | 240 | -- | -- | 512 | -- |
| 6/23/79 | 20.0 | 7.7 | 0.20 | 0.04 | -- | -- | 8.5 | 230 | 130 | 230 | < 10 | -- | 532 | -- |
| 6/24/79 | 19.0 | 7.9 | 0.10 | 0.02 | -- | -- | 9.0 | 230 | 135 | -- | -- | 6 | -- | 33 |
| 7/24/79 | 21.0 | 7.4 | 0.12 | 0.03 | -- | -- | 8.0 | 220 | 135 | -- | -- | -- | -- | -- |
| 7/25/79 | 21.5 | 7.5 | 0.10 | -- | 14.0 | 3.1 | 9.0 | 230 | 130 | 215 | 21 | 8 | 423 | 35 |
| 7/26/79 | 21.0 | 7.4 | 0.10 | -- | -- | -- | 8.5 | 225 | 145 | -- | -- | -- | -- | -- |
| 8/31/79 | 20.0 | -- | -- | -- | 13.5 | -- | -- | -- | -- | -- | -- | -- | 482 | -- |
| 9/1/79 | 20.0 | 7.7 | 0.10 | 0.03 | -- | 2.5 | -- | 230 | 190 | -- | -- | -- | -- | -- |
| 9/2/79 | 20.0 | -- | -- | -- | 13.5 | 2.5 | -- | 230 | 188 | 223 | 20 | < 5 | -- | -- |
| 9/25/79 | 15.5 | -- | 0.15 | 0.03 | 16.0 | -- | 9.0 | 250 | 130 | -- | -- | -- | -- | -- |
| 9/26/79 | 16.0 | -- | -- | -- | -- | -- | -- | 230 | 130 | -- | < 10 | -- | -- | -- |
| 9/27/79 | 15.0 | 7.6 | -- | -- | -- | -- | 10.0 | -- | -- | 234 | -- | < 5 | 467 | 7 |
| Mean | 19.0 | 7.6 | 0.12 | 0.03 | 14.3 | 2.7 | 8.9 | 230 | 144 | 228 | -- | -- | 508 | 25 |
| Maximum | 23.0 | 8.0 | 0.20 | 0.04 | 16.0 | 3.1 | 10.0 | 250 | 190 | 240 | 21 | 8 | 633 | 35 |
| Minimum | 15.0 | 7.1 | 0.10 | 0.02 | 13.5 | 2.5 | 8.0 | 220 | 130 | 215 | < 10 | < 5 | 423 | 7 |

## WATER QUALITY DATA FOR SOUTH McKITTRICK SAMPLE SITE #2

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/23/79 | 11.5 | 8.0 | 0.25 | 0.10 | 11.0 | -- | -- | 220 | 170 | -- | < 10 | < 5 | -- | 0 |
| 5/27/79 | 16.0 | 8.0 | 0.15 | 0.05 | 14.0 | 2.5 | 8.5 | 220 | 140 | 220 | < 10 | < 5 | 591 | -- |
| 6/22/79 | 20.0 | 7.2 | 0.20 | 0.05 | 14.0 | -- | 8.5 | 248 | 145 | 240 | -- | -- | 512 | -- |
| 6/23/79 | 17.0 | 7.8 | 0.25 | 0.05 | -- | -- | 8.5 | 250 | 140 | 250 | 11 | -- | 539 | -- |
| 6/24/79 | 16.5 | 7.7 | 0.10 | 0.02 | -- | -- | 9.0 | 240 | 140 | -- | -- | 7 | -- | 32 |
| 7/24/79 | 19.5 | 7.5 | 0.10 | 0.03 | -- | -- | 8.5 | 240 | 140 | -- | -- | -- | -- | -- |
| 7/25/79 | 21.0 | 7.5 | -- | -- | 14.0 | 2.6 | 9.0 | 240 | 145 | 225 | 17 | -- | 472 | -- |
| 7/26/79 | 19.0 | 7.4 | -- | -- | -- | -- | 9.5 | 235 | 160 | -- | -- | 6 | -- | 1 |
| 8/31/79 | 19.5 | -- | -- | -- | 11.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/1/79 | 22.0 | 7.5 | 0.20 | 0.03 | -- | 2.5 | -- | 240 | 190 | -- | -- | -- | -- | -- |
| 9/2/79 | 20.0 | -- | 0.20 | -- | 11.0 | 3.0 | -- | 240 | 175 | 228 | 13 | 6 | 495 | -- |
| 9/25/79 | 17.0 | -- | 0.15 | 0.05 | 17.0 | -- | 9.0 | 240 | 140 | -- | -- | -- | -- | -- |
| 9/26/79 | 19.0 | -- | -- | -- | -- | -- | -- | 240 | 160 | -- | < 10 | -- | -- | -- |
| 9/27/79 | 15.5 | 7.5 | -- | -- | -- | -- | 9.0 | -- | -- | 238 | -- | 6 | 479 | 32 |
| Mean | 18.1 | 7.6 | 0.18 | 0.05 | 13.1 | 2.6 | 8.8 | 238 | 154 | 234 | -- | -- | 515 | 16 |
| Maximum | 22.0 | 8.0 | 0.25 | 0.10 | 17.0 | 3.0 | 9.0 | 250 | 190 | 250 | 17 | 7 | 591 | 32 |
| Minimum | 11.5 | 7.2 | 0.10 | 0.02 | 11.0 | 2.5 | 8.5 | 220 | 140 | 220 | < 10 | < 5 | 479 | 0 |

## WATER QUALITY DATA FOR SOUTH McKITTRICK SAMPLE SITE #3

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/12/79 | 5.0 | 8.1 | -- | -- | 13.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2/2/79 | 4.0 | 8.4 | 0.30 | 0.05 | 12.0 | -- | 14.0 | -- | -- | -- | < 10 | < 5 | -- | -- |
| 3/23/79 | 12.5 | 7.8 | 0.25 | 0.06 | 11.0 | -- | -- | 240 | 170 | -- | < 10 | < 5 | -- | 0 |
| 5/21/79 | 17.0 | 7.8 | 0.15 | < 0.01 | 11.0 | 2.5 | 8.5 | 250 | 160 | 230 | < 10 | 6 | 676 | -- |
| 6/22/79 | 23.0 | 7.3 | 0.10 | 0.04 | 9.0 | -- | 8.5 | 275 | 195 | 260 | -- | -- | 580 | -- |
| 6/23/79 | 19.0 | 7.7 | 0.15 | 0.05 | -- | -- | 8.0 | 280 | 170 | 290 | < 10 | -- | 573 | -- |
| 6/24/79 | 17.0 | 7.6 | 0.10 | 0.03 | -- | -- | 9.0 | 275 | 180 | -- | -- | 7 | -- | 100 |
| 7/24/79 | 22.0 | 7.4 | 0.08 | 0.04 | -- | -- | 8.0 | 270 | 170 | -- | -- | -- | -- | -- |
| 7/25/79 | 23.5 | 7.5 | -- | -- | 5.0 | 2.5 | 7.5 | 270 | 170 | 246 | 17 | -- | 496 | -- |
| 7/26/79 | 21.5 | 7.4 | -- | -- | -- | -- | 8.0 | 270 | 180 | -- | -- | 5 | -- | 12 |
| 8/31/79 | 22.5 | -- | -- | -- | 9.0 | -- | -- | -- | -- | -- | -- | -- | 571 | -- |
| 9/1/79 | 22.0 | 7.5 | 0.20 | 0.02 | -- | 2.5 | -- | 250 | 175 | -- | -- | -- | -- | -- |
| 9/2/79 | 19.5 | -- | -- | -- | 11.0 | 2.5 | -- | 255 | 175 | 255 | < 10 | 10 | -- | -- |
| 9/25/79 | 18.0 | -- | 0.30 | 0.02 | 15.0 | -- | 9.0 | 280 | 160 | -- | -- | -- | -- | -- |
| 9/26/79 | 19.0 | -- | -- | -- | -- | -- | -- | 280 | 160 | -- | -- | 28 | -- | -- |
| 9/27/79 | 15.0 | 7.5 | -- | -- | -- | -- | 9.0 | -- | -- | 253 | -- | 8 | 521 | 12 |
| Mean | 17.5 | 7.7 | 0.18 | -- | 10.7 | 2.5 | 9.0 | 266 | 172 | 256 | -- | -- | 570 | 31 |
| Maximum | 23.5 | 8.4 | 0.30 | 0.05 | 15.0 | 2.5 | 14.0 | 280 | 190 | 290 | 17 | 28 | 676 | 100 |
| Minimum | 4.0 | 7.3 | 0.08 | < 0.01 | 9.0 | 2.5 | 7.5 | 240 | 160 | 230 | < 10 | < 5 | 496 | 0 |

## WATER QUALITY DATA FOR SOUTH McKITTRICK SAMPLE SITE #4

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/ cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/22/78 | 10.0 | 7.9 | -- | 0.25 | 10.5 | -- | 8.2 | -- | -- | 235 | -- | -- | -- | -- |
| 1/12/79 | 4.0 | 8.1 | -- | -- | 13.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2/2/79 | 4.0 | 8.4 | 0.30 | 0.13 | 14.0 | -- | 14.0 | -- | -- | -- | < 10 | < 5 | -- | -- |
| 3/23/79 | 12.0 | 8.0 | 0.30 | 0.08 | 9.0 | -- | -- | 240 | 140 | -- | < 10 | 4 | -- | 0 |
| 5/27/79 | 18.0 | 8.0 | 0.15 | < 0.01 | 3.0 | 3.8 | 8.0 | 260 | 190 | 230 | < 10 | 6 | 709 | -- |
| 6/11/79 | 23.0 | 7.0 | 0.10 | 0.03 | 7.0 | -- | 7.0 | 275 | 210 | 250 | -- | -- | 587 | -- |
| 6/23/79 | 20.0 | 7.8 | 0.25 | 0.08 | -- | -- | 8.0 | 270 | 180 | 260 | < 10 | -- | 580 | -- |
| 6/24/79 | 18.0 | 7.4 | 0.15 | 0.03 | -- | -- | 8.0 | 280 | 220 | -- | -- | 7 | -- | 96 |
| 7/24/79 | 23.5 | 7.5 | 0.09 | 0.03 | -- | -- | 8.0 | 270 | 175 | -- | -- | -- | -- | -- |
| 7/25/79 | 22.3 | 7.7 | -- | -- | 3.0 | 2.5 | 8.5 | 270 | 180 | 255 | 19 | 6 | 508 | 3 |
| 7/26/79 | 22.0 | 7.4 | -- | -- | -- | -- | 7.5 | 250 | 170 | -- | -- | -- | -- | -- |
| 8/31/79 | 22.0 | -- | -- | -- | 8.0 | -- | -- | -- | -- | -- | -- | -- | 596 | -- |
| 9/1/79 | 23.5 | 7.5 | 0.35 | 0.03 | -- | 2.5 | -- | 255 | 185 | -- | -- | -- | -- | -- |
| 9/2/79 | 20.0 | -- | -- | -- | 13.0 | 2.5 | -- | 250 | 182 | 260 | < 10 | 6 | -- | -- |
| 9/25/79 | 19.0 | -- | 0.15 | 0.04 | 13.0 | -- | 10.0 | 260 | 160 | -- | -- | -- | -- | -- |
| 9/26/79 | 20.0 | -- | -- | -- | -- | -- | -- | 260 | 130 | -- | < 10 | -- | -- | -- |
| 9/27/79 | 15.0 | 7.6 | -- | -- | -- | -- | 9.5 | -- | -- | 261 | -- | < 5 | 532 | -- |
| Mean | 17.4 | 7.7 | 0.20 | 0.07 | 9.4 | 2.8 | 8.8 | 262 | 177 | 250 | -- | -- | 585 | 33 |
| Maximum | 23.5 | 8.4 | 0.35 | 0.25 | 14.0 | 3.8 | 14.0 | 280 | 220 | 261 | 19 | 7 | 709 | 96 |
| Minimum | 4.0 | 7.0 | 0.09 | < 0.10 | 3.0 | 2.5 | 7.0 | 240 | 130 | 230 | < 10 | < 5 | 508 | 0 |

## WATER QUALITY DATA FOR SOUTH McKITTRICK SAMPLE SITE #5

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/ cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/22/78 | 12.0 | 8.0 | -- | 0.15 | -- | -- | 8.7 | -- | -- | 245 | -- | -- | -- | -- |
| 5/27/79 | 17.0 | 7.4 | 0.15 | < 0.01 | 5.0 | 3.8 | 8.5 | 250 | 160 | 220 | < 10 | 6 | 676 | -- |
| 6/22/79 | 23.0 | 7.8 | 0.15 | 0.02 | 3.0 | -- | 7.5 | 270 | 180 | 260 | -- | -- | 580 | -- |
| 6/23/79 | 22.0 | 7.8 | 0.25 | 0.06 | -- | -- | 9.5 | 280 | 180 | 280 | < 10 | -- | 580 | -- |
| 6/24/79 | 17.0 | 7.4 | 0.10 | 0.04 | -- | -- | 8.0 | 280 | 180 | -- | -- | 7 | -- | 32 |
| 7/24/79 | 24.0 | 7.5 | 0.10 | 0.05 | -- | -- | 8.0 | 270 | 170 | -- | -- | -- | -- | -- |
| 7/25/79 | 22.5 | 7.5 | -- | -- | 3.0 | 2.5 | 7.5 | 270 | 170 | 253 | 16 | -- | 508 | -- |
| 7/26/79 | 24.0 | 7.6 | -- | -- | -- | -- | 6.5 | 220 | 170 | -- | -- | 6 | -- | 2 |
| 8/31/79 | 27.0 | -- | -- | -- | 7.0 | -- | -- | -- | -- | -- | -- | -- | 603 | -- |
| 9/1/79 | 24.0 | 7.3 | 0.15 | 0.04 | -- | 2.5 | -- | 265 | 180 | -- | -- | -- | -- | -- |
| 9/2/79 | 22.0 | -- | -- | -- | 9.0 | 2.5 | -- | 260 | 175 | 251 | < 10 | < 5 | -- | -- |
| 9/25/79 | 19.5 | -- | 0.20 | 0.03 | 13.0 | -- | 9.0 | 250 | 160 | -- | -- | -- | -- | -- |
| 9/26/79 | 21.0 | -- | -- | -- | -- | -- | -- | 260 | 160 | -- | 32 | -- | -- | -- |
| 9/27/79 | 14.5 | 7.4 | -- | -- | -- | -- | 10.0 | -- | -- | 245 | -- | 6 | 521 | -- |
| Mean | 21.0 | 7.6 | 0.16 | 0.05 | 6.6 | 2.8 | 8.3 | 261 | 171 | 251 | -- | -- | 578 | 17 |
| Maximum | 27.0 | 8.0 | 0.25 | 0.06 | 13.0 | 3.8 | 10.0 | 280 | 180 | 280 | 32 | 7 | 676 | 32 |
| Minimum | 12.0 | 7.3 | 0.10 | < 0.01 | 3.0 | 2.5 | 6.5 | 220 | 160 | 220 | < 10 | < 5 | 508 | 2 |

## WATER QUALITY DATA FOR SOUTH McKITTRICK SAMPLE SITE #6

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/22/77 | -- | -- | 0.00 | 0.00 | 2.0 | -- | -- | 220 | 145 | -- | -- | -- | -- | 52 |
| 5/27/79 | 18.0 | 7.4 | 0.25 | < 0.01 | 12.0 | 2.5 | 9.0 | 270 | 175 | 220 | < 10 | 7 | 692 | -- |
| 6/22/79 | 23.0 | 8.0 | 0.10 | 0.03 | 10.0 | -- | 8.0 | 260 | 195 | 255 | -- | -- | 580 | -- |
| 6/23/79 | 16.0 | 7.8 | 0.30 | 0.07 | -- | -- | 8.0 | 280 | 180 | 250 | < 10 | -- | 614 | -- |
| 6/24/79 | 15.0 | 7.2 | 0.12 | 0.03 | -- | -- | 8.0 | 270 | 180 | -- | -- | 7 | -- | 5 |
| 7/24/79 | 23.0 | 7.5 | 0.15 | 0.03 | -- | -- | 9.0 | 270 | 170 | -- | -- | -- | -- | -- |
| 7/25/79 | 19.0 | 7.9 | -- | -- | 8.0 | 2.0 | 10.5 | 270 | 190 | 260 | 15 | 6 | 526 | 4 |
| 7/26/79 | 17.0 | 7.6 | -- | -- | -- | -- | 7.5 | 290 | 170 | -- | -- | -- | 622 | -- |
| 8/31/79 | 21.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/1/79 | 25.0 | 7.6 | 0.20 | 0.03 | -- | 2.5 | -- | 270 | 180 | -- | -- | -- | -- | -- |
| 9/2/79 | 27.0 | -- | -- | -- | 8.0 | 3.0 | -- | 265 | 180 | 287 | < 10 | < 5 | -- | -- |
| 9/25/79 | 18.0 | -- | 0.20 | 0.04 | 10.0 | -- | 8.0 | 280 | 170 | -- | -- | -- | -- | -- |
| 9/26/79 | 18.5 | -- | -- | -- | -- | -- | -- | 270 | 180 | -- | < 10 | -- | -- | -- |
| 9/27/79 | 14.0 | 7.5 | -- | -- | -- | -- | 9.0 | -- | -- | 266 | -- | < 5 | 568 | 0 |
| Mean | 19.6 | 7.6 | 0.16 | 0.03 | 8.0 | 2.5 | 8.6 | 268 | 176 | 256 | -- | -- | 600 | 20 |
| Maximum | 27.0 | 8.0 | 0.30 | 0.07 | 12.0 | 3.0 | 10.5 | 290 | 195 | 287 | 15 | 7 | 692 | 5 |
| Minimum | 14.0 | 7.2 | 0.00 | 0.00 | 2.0 | 2.0 | 7.5 | 260 | 170 | 220 | < 10 | < 5 | 526 | 0 |

# WATER QUALITY DATA FOR PRATT LODGE WELL

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/22/77 | -- | -- | 0.00 | 0.00 | 1.0 | -- | -- | 250 | 150 | -- | -- | -- | -- | 0 |
| 5/27/79 | 15.0 | 8.0 | 0.15 | 0.02 | 13.5 | 3.8 | -- | 290 | 165 | -- | -- | -- | -- | -- |
| 6/22/79 | 19.0 | 7.6 | 0.40 | 0.04 | 14.0 | -- | -- | 290 | 200 | 260 | -- | -- | 668 | -- |
| 6/23/79 | 16.5 | 7.6 | 0.30 | 0.05 | -- | -- | -- | 290 | 170 | -- | < 10 | -- | 662 | -- |
| 6/24/79 | 17.0 | 7.2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7/24/79 | 17.0 | 7.5 | 0.25 | 0.05 | -- | -- | -- | 300 | 195 | -- | -- | -- | -- | -- |
| 7/25/79 | 17.5 | 7.5 | -- | -- | 12.0 | 1.5 | -- | 290 | 170 | 273 | 14 | -- | 526 | 0 |
| 7/26/79 | 17.2 | 7.4 | 0.20 | -- | -- | -- | -- | 270 | 180 | -- | -- | -- | -- | -- |
| 9/1/79 | 17.0 | 7.2 | 0.80 | 0.03 | -- | 3.0 | -- | 290 | 240 | -- | -- | -- | -- | -- |
| 9/2/79 | 17.5 | -- | -- | -- | 14.0 | 2.5 | -- | 290 | 240 | 289 | < 10 | < 5 | 704 | -- |
| 9/25/79 | 17.0 | -- | 0.35 | 0.04 | 12.0 | 3.3 | -- | 290 | 190 | -- | -- | -- | -- | -- |
| 9/26/79 | 17.0 | -- | -- | -- | -- | -- | -- | 320 | 200 | -- | < 10 | -- | -- | -- |
| 9/27/79 | 16.5 | 7.6 | -- | -- | -- | -- | -- | -- | -- | 276 | -- | < 5 | 615 | 0 |
| Mean | 17.0 | 7.5 | 0.31 | 0.03 | 11.1 | 2.8 | -- | 288 | 191 | 275 | -- | -- | 635 | -- |
| Maximum | 19.0 | 8.0 | 0.80 | 0.05 | 14.0 | 3.8 | -- | 320 | 240 | 289 | 14 | < 5 | 704 | 0 |
| Minimum | 15.0 | 7.2 | 0.00 | 0.00 | 1.0 | 1.5 | -- | 250 | 150 | 260 | < 10 | < 5 | 526 | 0 |

# WATER QUALITY DATA FOR MAIN McKITTRICK SAMPLE SITE #7

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/ cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/22/77 | -- | -- | 0.20 | 0.00 | 2.0 | -- | -- | 250 | 160 | -- | -- | -- | -- | 15 |
| 5/27/79 | 11.0 | 7.4 | 0.30 | 0.02 | 12.0 | 2.5 | 9.0 | 280 | 165 | 188 | < 10 | 6 | 676 | -- |
| 6/22/79 | 20.0 | 7.6 | 0.20 | 0.04 | 8.0 | -- | 8.0 | 280 | 195 | 260 | -- | -- | 580 | -- |
| 6/23/79 | 17.0 | 8.0 | 0.25 | 0.05 | -- | -- | 8.5 | 270 | 180 | 260 | < 10 | -- | 614 | -- |
| 6/24/79 | 15.0 | 7.2 | 0.15 | 0.04 | -- | -- | 9.0 | 280 | 180 | -- | -- | < 5 | -- | 104 |
| 7/24/79 | 17.0 | 7.5 | 0.20 | 0.03 | -- | -- | 8.0 | 280 | 180 | -- | -- | -- | -- | -- |
| 7/25/79 | 16.5 | 7.2 | -- | -- | 10.0 | 1.5 | 9.5 | 280 | 180 | 260 | < 10 | -- | 581 | -- |
| 7/26/79 | 17.2 | 7.0 | -- | -- | -- | -- | 6.0 | 280 | 190 | -- | -- | < 5 | -- | -- |
| 8/31/79 | 16.5 | -- | -- | -- | 11.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/1/79 | 18.0 | 7.5 | 0.30 | -- | -- | 2.5 | -- | 290 | 200 | -- | -- | -- | -- | -- |
| 9/2/79 | 16.5 | -- | -- | -- | 11.0 | 2.5 | -- | 285 | 195 | 292 | 13 | 8 | 660 | -- |
| 9/25/79 | 17.0 | -- | 0.45 | 0.04 | -- | -- | 9.0 | 290 | 170 | -- | -- | -- | -- | -- |
| 9/26/79 | 16.5 | -- | -- | -- | -- | -- | -- | 300 | 180 | -- | 22 | -- | -- | -- |
| 9/27/79 | 14.5 | 7.6 | -- | -- | -- | -- | 9.0 | -- | -- | 248 | -- | < 5 | 592 | 1 |
| Mean | 16.4 | 7.4 | 0.26 | 0.03 | 9.0 | 2.3 | 8.4 | 280 | 181 | 251 | -- | -- | 617 | 40 |
| Maximum | 20.0 | 8.0 | 0.45 | 0.05 | 12.0 | 2.5 | 9.0 | 300 | 200 | 292 | 22 | 8 | 676 | 104 |
| Minimum | 11.0 | 7.0 | 0.15 | 0.00 | 8.0 | 1.5 | 6.0 | 250 | 160 | 188 | < 10 | < 5 | 580 | 1 |

## WATER QUALITY DATA FOR MAIN McKITTRICK SAMPLE SITE #8

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/ cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/22/79 | 16.0 | 7.8 | -- | -- | -- | -- | 7.3 | -- | -- | 245 | -- | -- | -- | -- |
| 1/12/79 | 13.0 | 7.9 | -- | -- | 10.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2/2/79 | 11.0 | 8.1 | 0.30 | 0.09 | 13.0 | -- | 9.5 | -- | -- | -- | < 10 | < 5 | -- | -- |
| 3/23/79 | 12.0 | 7.5 | 0.30 | 0.80 | 11.0 | -- | -- | 235 | 170 | -- | < 10 | < 5 | -- | 0 |
| 5/27/79 | 17.0 | 8.0 | 0.30 | 0.02 | 13.0 | 2.5 | 8.0 | 270 | 180 | 196 | < 10 | 7 | 709 | -- |
| 6/22/79 | 19.0 | 7.8 | 0.15 | 0.04 | 13.0 | -- | 8.5 | 280 | 195 | 250 | -- | -- | 587 | -- |
| 6/23/79 | 17.0 | 7.9 | 0.25 | 0.05 | -- | -- | 8.5 | 280 | 190 | 270 | < 10 | -- | 614 | -- |
| 6/24/79 | 15.0 | 7.0 | 0.20 | 0.04 | -- | -- | 9.0 | 280 | 180 | -- | -- | 6 | -- | 25 |
| 7/24/79 | 16.0 | 7.5 | 0.15 | 0.03 | -- | -- | 9.0 | 280 | 180 | -- | -- | -- | 581 | -- |
| 7/25/79 | 17.0 | 7.4 | -- | -- | 11.0 | 1.2 | 10.5 | 280 | 190 | 246 | 30 | -- | -- | -- |
| 7/26/79 | 19.2 | 7.4 | -- | -- | -- | -- | 8 0 | 280 | 170 | -- | -- | 6 | -- | 114 |
| 8/31/79 | 18.0 | -- | -- | -- | 12.0 | -- | -- | -- | -- | -- | -- | -- | 666 | -- |
| 9/1/79 | 18.5 | 7.4 | 0.15 | 0.02 | -- | 2.5 | -- | 285 | 200 | -- | -- | -- | -- | -- |
| 9/2/79 | 18.0 | -- | -- | -- | 12.0 | 2.5 | -- | 290 | 215 | 293 | < 10 | 6 | -- | -- |
| 9/25/79 | 17.5 | -- | 0.40 | 0.02 | 11.0 | -- | 8.5 | 280 | 180 | -- | -- | -- | -- | -- |
| 9/26/79 | 16.5 | -- | -- | -- | -- | -- | -- | 300 | 190 | -- | < 10 | -- | -- | -- |
| 9/27/79 | 15.0 | 7.7 | -- | -- | -- | -- | 9.0 | -- | -- | 266 | < 10 | < 5 | 592 | 3 |
| Mean | 16.2 | 7.7 | 0.24 | 0.12 | 11.8 | 2.2 | 8.7 | 278 | 187 | 252 | -- | -- | 625 | 46 |
| Maximum | 19.2 | 8.1 | 0.40 | 0.80 | 13.0 | 2.5 | 10.5 | 300 | 215 | 293 | 30 | 7 | 709 | 114 |
| Minimum | 11.0 | 7.0 | 0.15 | 0.02 | 10.0 | 1.2 | 7.3 | 235 | 170 | 196 | < 10 | < 5 | 581 | 0 |

## WATER QUALITY DATA FOR MAIN McKITTRICK SAMPLE SITE #9

| Date of Collection | Temp. C | pH | Nitrate-Nitrogen (mg/L) | Ortho-Phosphate (mg/L) | Sulfates (mg/L) | Chlorides (mg/L) | Dissolved Oxygen (mg/L) | Total Hardness (mg/L @ $CaCO_3$) | Calcium Hardness (mg/L @ $CaCO_3$) | Total Alkalinity (mg/L @ $CaCO_3$) | Total Suspended Solids (mg/L) | Chemical Oxygen Demand (mg/L) | Specific Conductance (micromhos/ cm @ 25C) | Total Coliform 100 ml. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/27/77 | -- | -- | 0.00 | 0.00 | 2.0 | -- | -- | 230 | 150 | -- | -- | -- | -- | 53 |

Note: Only sampled one time; stream dried up at this point after initial sampling.)

# APPENDIX D-- COMPUTER PROGRAM FOR REDUCING FIELD NOTES AND CHANNEL PROFILE DATA.

```
C     THIS PROGRAM REDUCES PROFILE SURVEY OBSERVATIONS WITH OR WITHOUT
C        RIGHT ANGLE OFFSET OBSERVATIONS, AND WRITES THE DATA SHEET FOR THE
C        SURVEY.
C
C     SEPARATE SURVEYS ARE DISTINGUISHED FROM EACH OTHER ON THE BASIS OF:
C
C        1. WATERSHED
C
C        2. LOCATION WITHIN A WATERSHED
C
C        3. DATA IDENTIFICATION (CROSS-SECTION OR LONGITUDINAL PROFILE)
C
C        4. DATE
C
C     THE DATA CARD FORMAT FOR PROFILE DATA IS:
C
C      CARD
C     COLUMNS  FIELD                       VARIABLE
C
C       1-4     A4    WATERSHED (10A6, WS-1, WS-6, WS-7, 8BBD, OR BOWL)
C       5-10   3I2    DATE (MONTH, DAY, YEAR)
C      11-12    A2    DATA TYPE (ALWAYS 'PR' FOR PROFILE SURVEY)
C        13     A1    DATA IDENTIFICATION ('C' FOR PROFILE PARALLEL TO FLOW
C                        AND 'T' FOR PROFILE PERPENDICULAR TO FLOW)
C      14-15    I2    LOCATION (1, 2, ETC.)
C      16-17   2X     --- BLANK ---
C      18-20    A3    STATION IDENTIFICATION ('TBM', 'TP', 'STA', OR BLANK)
C      21-27    F7.2  STATION (HORIZONTAL DISTANCE ALONG PROFILE LINE)
C      28-29   2X     --- BLANK ---
C      30-31    A2    ROD READING IDENTIFICATION ('BS' OR BLANK)
C      32-38    F7.3  ROD READING
C      39-40    I2    NUMBER OF OFFSET DATA TO BE READ
C      41-80    A40   REMARKS
C
C     THE DATA CARD FORMAT FOR OFFSET DATA IS:
C
C      CARD
C     COLUMNS  FIELD                       VARIABLE
C
C       1-4     A4    WATERSHED (10A6, WS-1, WS-6, WS-7, 8BBD, BOWL)
C       5-10   3I2    DATE (MONTH, DAY, YEAR)
C      11-12    A2    DATA TYPE (ALWAYS 'PR' FOR PROFILE SURVEY)
C        13     A1    DATA IDENTIFICATION ('C' FOR PROFILE PARALLEL TO FLOW
C                        AND 'T' FOR PROFILE PERPENDICULAR TO FLOW)
C      14-15    I2    LOCATION (1, 2, ETC.)
C      16-17    A2    DATA KIND ('RR' FOR ROD READING; 'CC' FOR DISTANCE
C                        ALONG OFFSET FROM CENTER LINE)
C      18-20    A3    PROFILE LINE STATION AT WHICH OFFSET IS TAKEN
```

```
C    21-80 12(F4.1, ROD READINGS AND WATER MARK NOTATIONS ('W' FOR ROD
C            A1)       READING TAKEN AT A WATER MARK, OTHERWISE BLANK)
C                    OR
C                   DISTANCE TO CENTER AND LEFT ('L') OR RIGHT ('R')
C                      NOTATIONS
C
C
C
      CHARACTER WS*4(2),DT*2,DI(2),STAI*3,RRI*2,RMKS*40,LR(16),W(16)
      DIMENSION IDATE(3,2),LO(2),MONTH(12),R(16),E(16),D(16)
      DATA MONTH /'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP',
     1'OCT','NOV','DEC'/
C
C    INITIALIZE WATERSHED
C
      WS(2)='    '
C
C    READ ONE CARD
C
   10 READ (5,1001,END=100) WS(1),(IDATE(I,1),I=1,3),DT,DI(1),LO(1),STAI
     1,STA,RRI,RR,IFLAG,RMKS
C
C    CHECK FOR THE START OF A NEW SURVEY.  IF DATA ARE FOR A NEW SURVEY,
C    THEN WRITE A NEW HEADING.  OTHERWISE, GO PROCESS THE DATA.
C
      IF (WS(1).NE.WS(2)) GO TO 20
      DO 12 I=1,3
        IF (IDATE(I,1).NE.IDATE(I,2)) GO TO 20
   12   CONTINUE
      IF (DI(1).NE.DI(2)) GO TO 20
      IF (LO(1).NE.LO(2)) GO TO 20
      GO TO 30
C
C    WRITE HEADING INFORMATION FOR NEW SURVEY
C
   20 WRITE (6,2001) WS(1)
      WRITE (6,2002) IDATE(2,1),MONTH(IDATE(1,1)),IDATE(3,1)
      IF (DI(1).EQ.'C') THEN DO
        WRITE (6,2003) LO(1)
          ELSE DO
        WRITE (6,2004) LO(1)
          END IF
      WRITE (6,2005)
C
C    SAVE WATERSHED, DATE, DATA I.D., AND LOCATION FOR RECOGNITION OF
C    DATA FROM A NEW SURVEY:  INITIALIZE ELEVATION AND FIRST-LINE FLAG.
C
      WS(2)=WS(1)
      DO 22 I=1,3
   22 IDATE(I,2)=IDATE(I,1)
      DI(2)=DI(1)
      LO(2)=LO(1)
      ELEV=100.
      IFLAG2=1
C
C  IDENTIFY ROD READING:  BACKSIGHT OR FORESIGHT
C
   30 IF (RRI.EQ.'BS') GO TO 35
C
C  FOR A FORESIGHT:  COMPUTE ELEVATION; WRITE LINE OF NOTES.
C  IF THERE ARE ANY OFFSET DATA, THEN READ THEM, COMPUTE ELEVATIONS,
C  AND WRITE THE NOTES:  THEN GO READ ANOTHER CARD.
C
      FS=RR
      IF (STAI.EQ.'TBM'.OR.STAI.EQ.'TP') THEN DO
        ELEV=HI-FS
          ELSE DO
        ELEV=INT((HI-FS)/.02+.6)*.02
          END IF
      IF (STAI.EQ.'   ') THEN DO
        IF (DI(1).EQ.'C') THEN DO
          WRITE (6,2012) STA,FS,ELEV,RMKS
            ELSE DO
          WRITE (6,2006) STA,FS,ELEV+.001,RMKS
            END IF
          ELSE DO
        ISTA=STA
        WRITE (6,2007) STAI,ISTA,FS,ELEV+.001,RMKS
          END IF
      IF (IFLAG.NE.0) THEN DO
        READ (5,1002) (R(I),W(I),I=1,IFLAG)
        READ (5,1002) (D(I),LR(I),I=1,IFLAG)
        DO 32 I=1,IFLAG
   32     E(I)=INT((HI-R(I))/.02+.6)*.02
        WRITE (6,2010) (E(I),W(I),I=1,IFLAG)
        WRITE (6,2011) (D(I),LR(I),I=1,IFLAG)
          END IF
      GO TO 10
C
C  FOR A BACKSIGHT:  COMPUTE HEIGHT OF INSTRUMENT:  WRITE THE LINE OF
C  NOTES:  THEN GO READ ANOTHER PROFILE SURVEY CARD.
C
   35 BS=RR
      HI=ELEV+BS
      ISTA=STA
      IF (IFLAG2.EQ.1) THEN DO
```

```
         WRITE (6,2008) STAI,ISTA,BS,HI+.COI.ELEV,RMKS
         IFLAG2=0
           ELSE DO
         WRITE (6,2009) STAI,ISTA,BS,HI+.COI.RMKS
           END IF
       GO TO 10
  100  STOP
 1001  FORMAT (A4,3I2,A2,A1,I2,2X,A3,F7.2,2X,A2,F7.3,I2,A40)
 1002  FORMAT ((20X,12(F4.1,A1)))
 2001  FORMAT ('1',12X,'WATERSHED:',2X,A4/)
 2002  FORMAT (' ',12X,'DATE:',2X,I2,1X,A3,1X,'19',I2/)
 2003  FORMAT (' ',12X,'DATA:',2X,'CHANNEL PROFILE GOING UPSTREAM FROM LO
      1CATION ',I2//)
 2004  FORMAT (' ',12X,'DATA:',2X,'CHANNEL CROSS-SECTION (TRANSECT) AT LO
      1CATION ',I2//)
 2005  FORMAT (' ',15X,'STATION',7X,'BS',10X,'HI',10X,'FS',7X,'ELEVATION'
      1,20X,'REMARKS'/)
 2006  FORMAT (15X,F6.1,31X,F5.2,7X,F7.2,5X,A40)
 2007  FORMAT (16X,A3,I2,31X,F5.2,7X,F7.2,5X,A40)
 2008  FORMAT (16X,A3,I2,7X,F5.2,6X,F7.2,18X,F7.2,5X,A40)
 2009  FORMAT (16X,A3,I2,7X,F5.2,6X,F7.2,30X,A40)
 2010  FORMAT (' ',5X,'ELEVATION      =',16(F6.1,A1))
 2011  FORMAT (' ',5X,'DIST TO CENTR =',16(F6.1,A1))
 2012  FORMAT (15X,F6.1,31X,F4.1,8X,F6.1,6X,A40)
       END
```

```
WATERSHED:  10A6

DATE:  15 APR 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  1

STATION      BS       HI        FS    ELEVATION                REMARKS

 TBM 1      2.46    102.46             100.00
   0.0                          3.01    99.46     TBM 1
   5.3                          3.30    99.16
  30.3                          5.38    97.08
  35.0                          6.17    96.30
  49.0                          6.48    95.98
  51.8                          7.10    95.36
  55.4                          8.38    94.08
  57.4                          9.37    93.10     BOTTOM
  59.1                          9.65    92.82     BOTTOM
  65.6                          9.52    92.94     BOTTOM
  70.5                          9.87    92.60     BOTTOM
  76.6                          9.88    92.58     BOTTOM
  78.3                         10.07    92.40     BOTTOM
  79.4                          4.85    97.62
  85.0                          4.53    97.94
  92.0                          4.79    97.68
  99.7                          5.03    97.44
 100.8                          5.21    97.26
 105.8                          5.36    97.10
 130.4                          5.75    96.72     TBM 2
 TBM 2                          5.23    97.23
 STA 1                          9.34    93.12   HIGH WATER MARK, ON PROFILE LINE
 STA 2                          9.20    93.26   HIGH WATER MARK, A FEW FEET DOWNSTREAM
 STA 3                          8.67    93.80   HIGH WATER MARK, A FEW FEET UPSTREAM
 TBM 1                          2.46   100.00
```

```
WATERSHED:  10A6

DATE:  14 APR 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  2

STATION     BS        HI          FS    ELEVATION                      REMARKS

 TBM 3     1.23     101.23                100.00
   0.0                           1.83      99.40       TBM 3
  32.5                           5.54      95.70
  36.0                           7.71      93.52
  42.5                           8.22      93.02
  47.6                          10.74      90.50       BOTTOM
  54.1                          11.56      89.68       BOTTOM
  59.1                          11.45      89.78       BOTTOM
  64.3                           8.24      93.00
  97.6                           8.22      93.02       TBM 4
 TBM 4                           7.63      93.60
 TBM 3                           1.23     100.00
```

WATERSHED: 10A6

DATE: 14 APR 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 2

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 3 | 1.22 | 101.22 | | 100.00 | |
| 0.0 | | | 11.6 | 89.7 | |
| 100.0 | | | 8.9 | 92.3 | |
| 156.0 | | | 8.0 | 93.2 | |
| TBM 3 | | | 1.22 | 100.00 | |

```
WATERSHED:  10A6

DATE:  14 APR 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  3

STATION      BS        HI         FS    ELEVATION                   REMARKS

 TBM 5      4.79     104.79              100.00       ON ROCK LEDGE BEHIND STEEL STAKE
   2.5                            7.40    97.40
   6.1                            7.70    97.10
  10.4                           12.50    92.30
  22.9                           15.67    89.12
  36.7                           16.80    88.00
  50.7                           14.65    90.14
  63.8                            4.43   100.36
 TBM 5                            4.79   100.00
```

```
WATERSHED:  10A6

DATE:  14 APR 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  4

STATION     BS        HI         FS    ELEVATION                      REMARKS

 TBM 6     2.88     102.88              100.00
   0.0                         3.87      99.02         TBM 6
  13.0                        11.89      91.00
  32.4                         7.56      95.32
  50.9                         2.14     100.74         TBM 7
 TBM 7                         0.82     102.06
 TBM 6                         2.88     100.00
```

WATERSHED: 10A6

DATE: 15 APR 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 5

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 9 | 3.73 | 103.73 | | 100.00 | |
| TBM 8 | | | 4.82 | 98.91 | |
| 0.0 | | | 5.12 | 98.62 | TBM 8 |
| 10.2 | | | 6.07 | 97.66 | |
| 25.3 | | | 10.21 | 93.52 | |
| 35.8 | | | 11.05 | 92.68 | |
| 37.8 | | | 11.47 | 92.26 | |
| 40.7 | | | 11.84 | 91.90 | |
| 47.7 | | | 10.80 | 92.94 | |
| 64.5 | | | 9.23 | 94.50 | |
| 75.7 | | | 10.66 | 93.08 | |
| 81.8 | | | 10.78 | 92.96 | |
| 84.5 | | | 11.19 | 92.54 | |
| 88.3 | | | 11.02 | 92.72 | |
| 96.6 | | | 10.98 | 92.76 | |
| 99.4 | | | 12.80 | 90.94 | |
| 103.0 | | | 13.27 | 90.46 | |
| 105.8 | | | 13.34 | 90.40 | |
| 109.1 | | | 12.67 | 91.06 | |
| 110.1 | | | 9.84 | 93.90 | |
| 127.6 | | | 10.45 | 93.28 | |
| 129.0 | | | 10.50 | 93.24 | |
| 130.9 | | | 10.13 | 93.60 | |
| 154.6 | | | 9.98 | 93.76 | |
| 158.1 | | | 10.24 | 93.50 | |
| 163.6 | | | 8.86 | 94.88 | |
| 182.1 | | | 5.81 | 97.92 | |
| 189.5 | | | 4.84 | 98.90 | TBM 9 |
| MSC 1 | | | 12.09 | 91.64 | HIGH WATER MARK |
| TBM 9 | | | 3.73 | 100.00 | |

WATERSHED: 10A6

DATE: 15 APR 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 5

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 9 | 3.73 | 103.73 |  | 100.00 |  |
| 0.0 |  |  | 13.2 | 90.5 |  |
| 100.0 |  |  | 10.2 | 93.5 |  |
| 140.0 |  |  | 9.1 | 94.6 |  |
| TBM 9 |  |  | 3.73 | 100.00 |  |

WATERSHED: 10A6

DATE: 15 APR 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 6

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM10 | 2.81 | 102.81 | | 100.00 | |
| 0.0 | | | 2.81 | 100.00 | TBM 10 |
| 1.3 | | | 3.55 | 99.26 | |
| 25.9 | | | 4.17 | 98.64 | |
| 28.7 | | | 4.63 | 98.18 | LARGE ROCK BETWEEN THIS STA. AND NEXT |
| 33.7 | | | 6.58 | 96.24 | |
| 46.4 | | | 8.68 | 94.14 | |
| 52.1 | | | 7.30 | 95.52 | |
| 63.5 | | | 7.12 | 95.70 | |
| 74.5 | | | 7.98 | 94.64 | |
| 80.0 | | | 8.80 | 94.02 | |
| 84.3 | | | 9.65 | 93.16 | |
| 86.9 | | | 10.25 | 92.56 | |
| 89.6 | | | 11.42 | 91.40 | |
| 98.1 | | | 12.48 | 90.34 | |
| 111.4 | | | 12.78 | 90.04 | |
| 120.7 | | | 13.94 | 88.88 | |
| 128.9 | | | 13.56 | 89.26 | LARGE ROCKS BETWEEN THIS STA. AND NEXT |
| 133.5 | | | 13.09 | 89.72 | |
| 139.6 | | | 14.89 | 87.92 | |
| 145.0 | | | 15.30 | 87.52 | |
| 169.3 | | | 13.34 | 89.48 | S. EDGE OF LARGE ROCKS |
| 188.4 | | | 13.48 | 89.34 | LARGE ROCK BETWEEN THIS STA. AND NEXT |
| 202.1 | | | 15.50 | 87.32 | |
| 212.3 | | | 18.36 | 84.46 | |
| TP 1 | | | 18.16 | 84.66 | |
| TP 1 | 2.91 | 87.57 | | | |
| 227.6 | | | 11.45 | 76.12 | |
| 234.6 | | | 11.07 | 76.50 | |
| 248.8 | | | 13.50 | 74.08 | |
| 258.4 | | | 12.24 | 75.34 | |
| 264.5 | | | 11.82 | 75.76 | |
| 271.0 | | | 12.44 | 75.14 | |
| 277.3 | | | 13.77 | 73.80 | BOTTOM. DEAD TREE AND LARGE ROCKS |
| 279.8 | | | 11.45 | 76.12 | |
| 282.3 | | | 11.13 | 76.44 | |

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 6 CONTINUED

| STATION | BS | HI | FS | ELEVATION | | REMARKS |
|---|---|---|---|---|---|---|
| 285.7 | | | 8.68 | 78.90 | | |
| 288.1 | | | 9.13 | 78.44 | | |
| 294.9 | | | 8.67 | 78.90 | BOTTOM | |
| TP 2 | | | 2.91 | 84.66 | | |
| TP 2 | 9.58 | 94.24 | | | | |
| TP 3 | | | 9.58 | 84.66 | | |
| TP 3 | 23.39 | 108.05 | | | | |
| 330.6 | | | 3.93 | 104.12 | TOP | |
| 332.6 | | | 3.44 | 104.62 | | |
| 336.6 | | | 3.95 | 104.10 | | |
| 347.6 | | | 4.23 | 103.82 | | |
| 358.6 | | | 4.50 | 103.56 | | |
| 360.1 | | | 3.45 | 104.60 | | |
| TBM11 | | | 3.45 | 104.60 | | |
| TP 4 | | | 23.39 | 84.66 | | |
| TP 4 | 18.22 | 102.88 | | | | |
| TBM10 | | | 2.87 | 100.01 | | |

```
WATERSHED:   10A6

DATE:   15 APR 1979

DATA:   CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  6

STATION      BS        HI        FS    ELEVATION                    REMARKS

  TBM10     2.81     102.81             100.00
   TP 1                       18.16      84.66
   TP 1     2.91      87.57
   TP 2                        2.91      84.66
   TP 2     9.58      94.24
    0.0                       20.7       73.5
  100.0                       12.1       82.1
   TP 3                        9.58      84.66
   TP 3    23.39     108.05
  200.0                       17.1       91.0
  300.0                        6.6      101.5
   TP 4                       23.39      84.66
   TP 4    18.22     102.88
  TBM10                        2.87     100.01
```

WATERSHED: WS-1

DATE: 17 MAY 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 1

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 3.91 | 103.91 | | 100.00 | |
| 0.0 | | | 4.81 | 99.10 | TBM 1 |
| 20.0 | | | 12.09 | 91.82 | |
| 20.7 | | | 12.34 | 91.58 | |
| 45.0 | | | 16.94 | 86.98 | HIGH WATER MARK |
| 48.0 | | | 17.45 | 86.46 | |
| 59.9 | | | 18.21 | 85.70 | CHANNEL BOTTOM (ROCKS) |
| 69.4 | | | 18.39 | 85.52 | CHANNEL BOTTOM (ROCKS) |
| 77.9 | | | 18.38 | 85.54 | CHANNEL BOTTOM (ROCKS AND GRASS) |
| TP 1 | | | 16.43 | 87.48 | |
| TP 1 | 8.30 | 95.78 | | | |
| 94.5 | | | 9.78 | 86.00 | CHANNEL BOTTOM (ROCKS AND GRASS) |
| 100.0 | | | 9.21 | 86.58 | JUST E. OF 2 FT DIA. LOG |
| 115.3 | | | 8.86 | 86.92 | |
| 123.9 | | | 8.10 | 87.68 | |
| 143.4 | | | 9.03 | 86.76 | |
| 150.0 | | | 8.77 | 87.02 | |
| 159.9 | | | 7.96 | 87.82 | |
| 171.3 | | | 4.45 | 91.34 | |
| 178.4 | | | 3.73 | 92.06 | TBM 2 |
| TBM 2 | | | 2.67 | 93.11 | |
| TP 2 | | | 8.30 | 87.48 | |
| TP 2 | 2.81 | 90.29 | | | |
| TP 3 | | | 2.11 | 88.18 | |
| TP 3 | 6.96 | 95.14 | | | |
| TP 4 | | | 6.96 | 88.18 | |
| TP 4 | 2.07 | 90.25 | | | |
| TP 5 | | | 2.76 | 87.50 | |
| TP 5 | 0.47 | 87.97 | | | |
| TP 6 | | | 0.47 | 87.50 | |
| TP 6 | 15.29 | 102.79 | | | |
| TBM 1 | | | 2.79 | 100.00 | |

WATERSHED: WS-1

DATE: 17 MAY 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 1

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 3.91 | 103.91 | | 100.00 | |
| TP 1 | | | 16.43 | 87.48 | |
| TP 1 | 8.30 | 95.78 | | | |
| TP 2 | | | 8.30 | 87.48 | |
| TP 2 | 2.81 | 90.29 | | | |
| 0.0 | | | 4.5 | 85.8 | |
| -67.1 | | | 6.6 | 83.7 | |
| -67.8 | | | 9.7 | 80.6 | TOP EDGE OF GULLY HEADWALL WEST |
| -74.0 | | | 13.6 | 76.7 | BOTTOM EDGE OF GULLY HEADWALL WEST |
| -67.4 | | | 6.8 | 83.5 | HOLE IN GULLY BOTTOM AT HEAD WEST |
| -68.6 | | | 9.4 | 80.9 | TOP EDGE OF GULLY HEADWALL EAST |
| -73.9 | | | 12.4 | 77.9 | BOTTOM EDGE OF GULLY HEADWALL EAST |
| -82.6 | | | 11.3 | 79.0 | HOLE IN GULLY BOTTOM AT HEAD EAST |
| -100.0 | | | 11.9 | 78.4 | CHANNEL BOTTOM DOWNSTREAM FROM HEAD |
| 100.0 | | | 3.2 | 87.1 | |
| 200.0 | | | 2.5 | 87.8 | |
| TP 3 | | | 2.11 | 88.18 | EDGE OF HOLE BEHIND LARGE ROCK |
| TP 3 | 6.96 | 95.14 | | | |
| 300.0 | | | 4.0 | 91.1 | |
| 300.0 | | | 4.7 | 90.4 | |
| 400.0 | | | 4.2 | 90.9 | 5.3 FT W. OF PREVIOUS STATION |
| 500.0 | | | 2.6 | 92.5 | |
| TP 4 | | | 6.96 | 88.18 | |
| TP 4 | 2.07 | 90.25 | | | |
| TP 5 | | | 2.76 | 87.50 | |
| TP 5 | 0.47 | 87.97 | | | |
| -200.0 | | | 10.9 | 77.1 | |
| -250.0 | | | 12.2 | 75.8 | |
| TP 6 | | | 0.47 | 87.50 | |
| TP 6 | 15.29 | 102.79 | | | |
| TBM 1 | | | 2.79 | 100.00 | |

WATERSHED: WS-1

DATE: 17 MAY 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 2

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 3 | 1.41 | 101.41 | | 100.00 | |
| 0.0 | | | 2.44 | 98.98 | TBM 3 |
| 5.2 | | | 3.11 | 98.30 | |
| 13.7 | | | 7.67 | 93.74 | |
| 24.5 | | | 15.13 | 86.28 | GAME TRAIL |
| 36.7 | | | 21.81 | 79.60 | HIGH WATER MARK |
| 37.7 | | | 22.69 | 78.72 | CHANNEL BOTTOM |
| 40.7 | | | 22.87 | 78.54 | |
| 43.8 | | | 23.41 | 78.00 | |
| 48.6 | | | 23.62 | 77.80 | |
| 50.5 | | | 23.35 | 78.06 | |
| 52.8 | | | 22.54 | 78.88 | |
| 54.1 | | | 22.35 | 79.06 | |
| 56.3 | | | 22.59 | 78.82 | |
| 58.5 | | | 22.12 | 79.30 | |
| 60.8 | | | 22.00 | 79.42 | |
| 64.4 | | | 21.09 | 80.32 | |
| 78.1 | | | 14.53 | 86.88 | |
| 89.1 | | | 8.22 | 93.20 | |
| 99.7 | | | 4.83 | 96.58 | |
| 112.6 | | | 4.43 | 96.98 | |
| 115.8 | | | 3.77 | 97.64 | |
| 118.5 | | | 2.76 | 98.66 | TBM 4 |
| TBM 4 | | | 1.78 | 99.63 | |
| TBM 3 | | | 1.41 | 100.00 | |

```
WATERSHED:  WS-1

DATE:  17 MAY 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  2

STATION      BS        HI        FS     ELEVATION                          REMARKS

 TBM 3      1.41     101.41              100.00
  TP 1                         21.88      79.54
  TP 1      6.78      86.32
   0.0                          8.6       77.7
 100.0                          4.4       81.9
ELEVATION      =  85.0   84.0   82.2     82.0    82.8    82.9    81.9    82.4   83.4W  84.6
DIST FM CENTR  =  18.4L  14.6L  13.7L    10.7L    8.4L    5.9L    0.0C    8.0R  10.0R  13.0R
  TP 2                          0.17      86.16
  TP 2      4.50      90.66
 200.0                          5.6       85.1
ELEVATION      =  89.7   86.8   86.0     85.1    85.4    87.1W   90.6
DIST FM CENTR  =  21.9L  13.6L   6.3L     0.0C    1.8R    3.9R   11.5R
 275.0                          3.3       87.4
ELEVATION      =  93.3V  87.5   87.4     89.3W   89.8    95.2
DIST FM CENTR  =   3.0L   3.0L   0.0C     9.6R   11.4R   22.4R
  TP 3                          4.50      86.16
  TP 3      7.14      93.30
  TP 4                          3.17      90.14
  TP 4     15.48     105.62
  TP 5                          5.23     100.40
  TP 5      1.48     101.88
 TBM 3                          1.85     100.03
```

WATERSHED: WS-1

DATE: 18 MAY 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 3

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 5 | 1.88 | 101.88 | | 100.00 | |
| 0.0 | | | 2.44 | 99.44 | TBM 5 |
| 6.7 | | | 2.81 | 99.08 | |
| 12.1 | | | 3.72 | 98.16 | S. EDGE OF ROAD |
| 14.1 | | | 4.15 | 97.74 | S. RUT OF ROAD |
| 16.3 | | | 4.47 | 97.42 | CENTER LINE OF ROAD |
| 19.6 | | | 4.56 | 97.32 | N. RUT OF ROAD |
| 21.6 | | | 4.66 | 97.22 | N. EDGE OF ROAD |
| 36.4 | | | 6.72 | 95.16 | S. EDGE OF TRAIL |
| 39.2 | | | 7.30 | 94.58 | CENTER LINE OF TRAIL |
| 41.4 | | | 7.50 | 94.38 | N. EDGE OF TRAIL - BOTTOM |
| 42.2 | | | 7.36 | 94.52 | N. EDGE OF TRAIL - TOP |
| 53.7 | | | 9.49 | 92.40 | |
| 66.3 | | | 12.60 | 89.28 | |
| 86.9 | | | 14.18 | 87.70 | |
| 92.6 | | | 16.73 | 85.16 | |
| 93.9 | | | 16.79 | 85.10 | |
| 96.0 | | | 17.69 | 84.20 | |
| 100.0 | | | 17.07 | 84.82 | |
| 101.3 | | | 16.75 | 85.14 | HIGH WATER MARK |
| 120.5 | | | 8.38 | 93.50 | |
| 128.5 | | | 4.40 | 97.48 | |
| 131.4 | | | 3.48 | 98.40 | |
| 137.8 | | | 3.34 | 98.54 | TBM 6 |
| TBM 6 | | | 2.84 | 99.04 | |
| TBM 5 | | | 1.88 | 100.00 | |

```
WATERSHED:  WS-1

DATE:   18 MAY 1979

DATA:   CHANNEL PROFILE GOING UPSTREAM FROM LOCATION   3

STATION      BS          HI          FS     FLEVATION                         REMARKS

  TBM 5     1.81       101.81                100.00
   TP 1                            14.75      87.06
   TP 1     2.51        89.57
    0.0                             5.4       84.2
  -42.4                             7.8       81.8         TOP OF ROCK OVERFALL
  -43.1                            11.5       78.1         BOTTOM OF ROCK OVERFALL
 -100.0                            15.5       74.1
   TP 2                            19.58      70.00
   TP 2     0.20        70.20
 -200.0                             6.4       63.8
 -300.0                            14.0       56.2
   TP 3                             0.20      70.00
   TP 3    19.55        89.55
   TP 4                             2.63      86.92
   TP 4    12.21        99.13
  100.0                             8.7       90.4
FLEVATION      =    93.1R   91.9R   90.9    90.4    91.0    90.4    92.4    93.3
DIST FM CENTR  =    24.9L   13.4L    3.8L    0.0C    5.0R   10.0R   13.7R   19.6R
  200.0                             4.0       95.1
FLEVATION      =    97.7    96.0W   95.7    95.8    95.1    95.6    95.7    96.5    97.2
DIST FM CENTR  =    16.5L    8.1L    6.0L    3.3L    0.0C    3.2R    5.3R   12.1R   19.2R
   TP 5                             2.64      96.50
   TP 5     6.99       103.49
  300.0                             5.7       97.8
FLEVATION      =    99.7    98.1    97.8    98.0    99.8
DIST FM CENTR  =    11.2L    7.1L    0.0C    2.0R    6.8R
   TP 6                             9.05      95.44
   TP 6    10.98       106.42
  TBM 5                             6.41     100.01
```

WATERSHED: WS-1

DATE: 19 MAY 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 4

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 7 | 0.79 | 100.79 | | 100.00 | |
| 0.0 | | | 1.93 | 98.86 | TBM 7 |
| 4.4 | | | 3.03 | 97.76 | |
| 16.6 | | | 4.98 | 95.92 | |
| 23.2 | | | 7.13 | 93.66 | |
| 31.5 | | | 9.89 | 90.90 | |
| 39.3 | | | 11.31 | 89.48 | TOP EDGE OF CHANNEL |
| 41.3 | | | 12.27 | 88.52 | BOTTOM EDGE OF CHANNEL |
| 45.1 | | | 12.30 | 88.50 | |
| 48.2 | | | 11.97 | 88.82 | |
| 52.5 | | | 10.88 | 89.92 | |
| 55.1 | | | 11.13 | 89.66 | |
| 56.2 | | | 11.70 | 89.10 | |
| 59.5 | | | 12.28 | 88.52 | |
| 63.6 | | | 11.03 | 89.76 | |
| 67.3 | | | 10.34 | 90.46 | |
| 69.6 | | | 9.30 | 91.50 | HIGH WATER MARK |
| TP 1 | | | 3.75 | 97.04 | |
| TP 1 | 5.31 | 102.35 | | | |
| 78.7 | | | 5.80 | 96.56 | |
| 88.0 | | | 5.41 | 96.94 | |
| 100.0 | | | 4.91 | 97.44 | |
| 102.7 | | | 4.84 | 97.52 | |
| 118.3 | | | 5.51 | 96.84 | |
| 123.5 | | | 5.50 | 96.86 | |
| 130.4 | | | 4.16 | 98.20 | |
| 135.2 | | | 2.83 | 99.52 | TBM 8 |
| TBM 8 | | | 2.15 | 100.20 | |
| TP 2 | | | 11.19 | 91.16 | |
| TP 2 | 6.34 | 97.50 | | | |
| TP 3 | | | 3.07 | 94.44 | |
| TP 3 | 5.13 | 99.57 | | | |
| TP 4 | | | 6.25 | 93.32 | |
| TP 4 | 0.96 | 94.28 | | | |
| TP 5 | | | 0.27 | 94.02 | |
| TP 5 | 6.90 | 100.92 | | | |
| TBM 7 | | | 0.89 | 100.03 | |

WATERSHED: WS-1

DATE: 19 MAY 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 4

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 7 | 0.79 | 100.79 | | 100.00 | |
| TP 1 | | | 3.75 | 97.04 | |
| TP 1 | 5.31 | 102.35 | | | |
| TP 2 | | | 11.19 | 91.16 | |
| TP 2 | 6.34 | 97.50 | | | |
| 100.0 | | | 6.6 | 90.9 | |
| 200.0 | | | 3.8 | 93.7 | |
| TP 3 | | | 3.07 | 94.44 | |
| TP 3 | 5.13 | 99.57 | | | |
| 300.0 | | | 4.9 | 94.7 | |
| 400.0 | | | 2.3 | 97.3 | |
| TP 4 | | | 6.25 | 93.32 | |
| TP 4 | 0.96 | 94.28 | | | |
| 0.0 | | | 5.9 | 88.4 | |
| TP 5 | | | 0.27 | 94.02 | |
| TP 5 | 6.90 | 100.92 | | | |
| TBM 7 | | | 0.89 | 100.03 | |

WATERSHED: WS-1

DATE: 19 MAY 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 5

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 9 | 12.18 | 112.18 | | 100.00 | |
| TP 1 | | | 2.11 | 110.08 | |
| TP 1 | 4.63 | 114.71 | | | |
| 0.0 | | | 1.88 | 112.84 | TOP OF STEEL STAKE |
| 0.0 | | | 2.50 | 112.22 | GROUND |
| 8.7 | | | 5.45 | 109.26 | |
| 9.5 | | | 6.77 | 107.94 | |
| 14.0 | | | 9.70 | 105.02 | |
| 25.1 | | | 14.35 | 100.36 | |
| STA 2 | | | 14.64 | 100.08 | S. SIDE HIGH WATER MARK (ABOUT 0+25.0) |
| 28.3 | | | 16.66 | 98.06 | |
| 33.9 | | | 16.89 | 97.82 | LARGE ROCK BETWEEN THIS STA. AND NEXT |
| 39.0 | | | 16.20 | 98.52 | |
| 40.3 | | | 16.37 | 98.34 | LARGE ROCK BETWEEN THIS STA. AND NEXT |
| 42.5 | | | 14.28 | 100.44 | |
| STA 1 | | | 13.62 | 101.10 | N. SIDE HIGH WATER MARK (ABOUT 0+48.0) |
| 48.9 | | | 13.38 | 101.34 | |
| 57.3 | | | 9.23 | 105.48 | |
| 60.0 | | | 8.44 | 106.28 | |
| 70.0 | | | 4.35 | 110.36 | |
| 76.1 | | | 1.62 | 113.10 | GROUND |
| 76.1 | | | 0.96 | 113.76 | TOP OF STEEL STAKE |
| TP 2 | | | 15.40 | 99.32 | |
| TP 2 | 6.10 | 105.42 | | | |
| TP 3 | | | 1.88 | 103.54 | |
| TP 3 | 9.36 | 112.90 | | | |
| TP 4 | | | 7.97 | 104.94 | |
| TP 4 | 0.58 | 105.52 | | | |
| TP 5 | | | 8.21 | 97.32 | |
| TP 5 | 6.82 | 104.14 | | | |
| TBM 9 | | | 4.14 | 100.00 | |

WATERSHED: WS-1

DATE: 19 MAY 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 5

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 9 | 12.18 | 112.18 |  | 100.00 |  |
| TP 1 |  |  | 2.11 | 110.08 |  |
| TP 1 | 4.63 | 114.71 |  |  |  |
| TP 2 |  |  | 15.40 | 99.32 |  |
| TP 2 | 6.10 | 105.42 |  |  |  |
| 0.0 |  |  | 7.5 | 97.9 |  |
| 50.0 |  |  | 5.1 | 100.3 |  |
| TP 3 |  |  | 1.88 | 103.54 |  |
| TP 3 | 9.36 | 112.90 |  |  |  |
| 100.0 |  |  | 6.9 | 106.0 |  |
| 200.0 |  |  | 3.7 | 109.2 |  |
| 250.0 |  |  | 0.8 | 112.1 |  |
| TP 4 |  |  | 7.97 | 104.94 |  |
| TP 4 | 0.58 | 105.52 |  |  |  |
| TP 5 |  |  | 8.21 | 97.32 |  |
| TP 5 | 6.82 | 104.14 |  |  |  |
| TBM 9 |  |  | 4.14 | 100.00 |  |

```
WATERSHED:  WS-6

DATE:    7 JUN 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  1

STATION      BS        HI          FS     ELEVATION                         REMARKS

 TBM 1      1.63     101.63                100.00
   0.0                              2.08    99.56     TBM 1
  20.2                              6.58    95.06
  30.5                              9.43    92.20
  41.2                             14.18    87.46
  54.0                             20.76    80.88
  64.0                             24.69    76.94
  TP 1                             23.24    78.40
  TP 1      3.10      81.50
  77.6                              7.43    74.08
 104.7                              8.58    72.92     ROAD CENTER
 127.0                              7.76    73.74
 142.3                              5.88    75.62
 153.5                              5.87    75.64
 167.3                              6.38    75.12
 181.6                              5.52    75.98
 200.0                              5.58    75.92
 228.1                              5.91    75.60
 242.6                              7.24    74.26
 261.7                              5.90    75.60
 297.5                              5.39    76.12
 300.0                              5.53    75.98
  TP 2                              5.36    76.14
  TP 2      3.88      80.02
 305.3                              4.51    75.52
 317.1                              5.84    74.18
 326.8                             10.58    69.44
 341.0                             17.85    62.18
 348.6                             19.71    60.32
 368.3                             20.79    59.24
 375.8                             22.04    57.98     BASE OF LARGE ROCK
 378.8                             20.00    60.02     ON LARGE ROCK
 380.8                             22.06    57.96     BASE OF LARGE ROCK
 399.7                             22.21    57.82
 422.3                             22.03    58.00
 429.2                             20.98    59.04
```

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 1 CONTINUED

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| 438.2 | | | 15.63 | 64.40 | |
| 440.0 | | | 15.42 | 64.60 | |
| 449.0 | | | 10.72 | 69.30 | ON LARGE ROCK |
| 450.7 | | | 12.30 | 67.72 | |
| 463.0 | | | 6.00 | 74.02 | |
| TP 3 | | | 2.69 | 77.34 | |
| TP 3 | 24.21 | 101.55 | | | |
| 474.0 | | | 19.39 | 82.16 | |
| 486.0 | | | 11.35 | 90.20 | |
| 497.0 | | | 3.15 | 98.40 | |
| 497.0 | | | 2.58 | 98.98 | TOP OF STAKE |
| TBM 1 | | | 1.48 | 100.07 | |

```
WATERSHED:  WS-6

DATE:   8 JUN 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  1

STATION      BS        HI         FS    ELEVATION                  REMARKS

 TBM 1      9.87     109.87              100.00
   0.0                            9.9    100.0    CROSS SECTION STATION 3+75.8
   0.0                            5.3    104.6    NE SIDF HIGH WATER MARK
   0.0                            5.3    104.6    SW SIDF HIGH WATER MARK
 100.0                           10.2     99.7    SCOUR HOLE
 200.0                            8.7    101.2
 300.0                            8.6    101.3
 350.0                            7.5    102.4
 TBM 1                            9.87   100.00
```

WATERSHED: WS-6

DATE: 10 JUN 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 2

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 8.38 | 108.38 | | 100.00 | |
| 0.0 | | | 0.23 | 108.16 | TOP OF STAKE |
| 0.0 | | | 1.10 | 107.28 | GROUND |
| 16.9 | | | 4.58 | 103.80 | |
| 24.2 | | | 5.06 | 103.32 | |
| 27.3 | | | 5.46 | 102.92 | |
| 39.6 | | | 6.93 | 101.46 | |
| 45.1 | | | 7.26 | 101.12 | |
| 51.7 | | | 8.33 | 100.06 | |
| 60.2 | | | 8.98 | 99.40 | |
| 69.5 | | | 11.09 | 97.30 | |
| 72.6 | | | 11.90 | 96.48 | |
| 77.5 | | | 14.14 | 94.24 | |
| 82.0 | | | 14.29 | 94.10 | |
| 89.1 | | | 14.05 | 94.34 | |
| 94.4 | | | 15.29 | 93.10 | |
| 100.0 | | | 14.76 | 93.62 | |
| 108.9 | | | 14.42 | 93.96 | |
| 110.1 | | | 15.66 | 92.72 | |
| 111.7 | | | 16.25 | 92.14 | |
| TP 1 | | | 14.55 | 93.84 | |
| TP 1 | 3.40 | 97.24 | | | |
| 114.5 | | | 4.43 | 92.82 | |
| 121.0 | | | 5.51 | 91.74 | |
| 122.9 | | | 5.82 | 91.42 | |
| 126.8 | | | 5.55 | 91.70 | |
| 129.0 | | | 5.91 | 91.34 | |
| 131.4 | | | 5.66 | 91.58 | |
| 132.4 | | | 6.61 | 90.64 | |
| 133.9 | | | 6.56 | 90.68 | |
| 140.6 | | | 5.92 | 91.32 | |
| 149.0 | | | 6.10 | 91.14 | |
| 160.9 | | | 5.70 | 91.54 | |
| 168.5 | | | 6.09 | 91.16 | |
| 169.8 | | | 5.75 | 91.50 | |
| 171.4 | | | 6.42 | 90.82 | |

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 2 CONTINUED

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| 178.3 | | | 6.46 | 90.78 | TRAIL |
| 183.0 | | | 7.16 | 90.08 | |
| 186.1 | | | 5.71 | 91.54 | |
| TP 2 | | | 1.69 | 95.56 | |
| TP 2 | 3.39 | 98.95 | | | |
| TP 3 | | | 3.39 | 95.56 | |
| TP 3 | 3.12 | 98.68 | | | |
| STA 1 | | | 5.70 | 92.98 | HIGH WATER MARK |
| TP 4 | | | 1.55 | 97.14 | |
| TP 4 | 11.35 | 108.49 | | | |
| 193.5 | | | 6.57 | 101.92 | |
| 195.3 | | | 5.42 | 103.08 | |
| 197.3 | | | 4.72 | 103.78 | |
| 197.9 | | | 3.63 | 104.86 | |
| 199.7 | | | 3.52 | 104.96 | |
| 201.2 | | | 2.06 | 106.44 | |
| 203.6 | | | 1.27 | 107.22 | |
| 205.5 | | | 0.96 | 107.54 | |
| 205.5 | | | 0.12 | 108.38 | TOP OF STAKE |
| TBM 1 | | | 8.46 | 100.03 | |

WATERSHED: WS-6

DATE: 10 JUN 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 2

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 8.38 | 108.38 |  | 100.00 |  |
| TP 1 |  |  | 14.55 | 93.84 |  |
| TP 1 | 3.40 | 97.24 |  |  |  |
| 0.0 |  |  | 7.2 | 90.0 | CROSS-SECTION STATION 1+83.0 |
| 100.0 |  |  | 5.5 | 91.7 |  |
| TP 2 |  |  | 1.69 | 95.56 |  |
| TP 2 | 3.39 | 98.95 |  |  |  |
| 200.0 |  |  | 6.2 | 92.8 |  |
| 300.0 |  |  | 3.4 | 95.6 |  |
| 400.0 |  |  | 1.0 | 98.0 |  |
| TP 3 |  |  | 3.39 | 95.56 |  |
| TP 3 | 3.12 | 98.68 |  |  |  |
| TP 4 |  |  | 1.55 | 97.14 |  |
| TP 4 | 11.35 | 108.49 |  |  |  |
| TBM 1 |  |  | 8.46 | 100.03 |  |

WATERSHED: WS-6

DATE: 19 JUN 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 3

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 1.32 | 101.32 | | 100.00 | STATION 0+00, TOP OF STAKE |
| 0.0 | | | 1.99 | 99.34 | |
| 11.7 | | | 4.87 | 96.46 | |
| 23.0 | | | 5.45 | 95.88 | |
| 35.0 | | | 5.20 | 96.12 | |
| 42.5 | | | 4.59 | 96.74 | |
| 56.4 | | | 4.91 | 96.42 | |
| 69.0 | | | 5.19 | 96.14 | |
| 77.6 | | | 5.69 | 95.64 | |
| 82.0 | | | 6.04 | 95.29 | |
| 87.6 | | | 6.70 | 94.62 | |
| 90.7 | | | 7.80 | 93.52 | |
| 95.1 | | | 8.69 | 92.64 | |
| 99.1 | | | 9.61 | 91.72 | |
| 105.6 | | | 9.99 | 91.34 | |
| 109.0 | | | 10.68 | 90.64 | |
| 115.1 | | | 10.98 | 90.34 | |
| 120.5 | | | 10.73 | 90.60 | |
| 125.1 | | | 10.35 | 90.98 | |
| 136.[illegible] | | | 9.91 | 91.42 | |
| 142.5 | | | 10.27 | 91.06 | |
| 144.3 | | | 11.44 | 89.88 | |
| 146.8 | | | 11.60 | 89.72 | |
| 151.5 | | | 11.45 | 89.88 | |
| 153.[illegible] | | | 10.93 | 90.40 | |
| 154.0 | | | 10.79 | 90.54 | |
| 155.3 | | | 10.36 | 90.97 | |
| 157.0 | | | 10.66 | 90.66 | |
| 158.3 | | | 10.64 | 90.68 | |
| 161.7 | | | 9.48 | 91.84 | |
| 164.8 | | | 8.18 | 93.14 | |
| 166.5 | | | 7.17 | 94.16 | |
| 167.3 | | | 6.36 | 94.96 | |
| 170.9 | | | 5.05 | 96.28 | |
| 175.8 | | | 2.63 | 98.70 | |
| TP 1 | | | 10.54 | 90.78 | |

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 3 CONTINUED

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TP 1 | 6.31 | 97.09 | | | |
| TP 2 | | | 6.18 | 90.92 | |
| TP 2 | 13.20 | 104.12 | | | |
| 179.6 | | | 5.05 | 99.08 | |
| 196.7 | | | 4.61 | 99.52 | |
| 212.8 | | | 6.03 | 98.10 | |
| 237.1 | | | 7.67 | 96.46 | |
| TP 3 | | | 8.11 | 96.02 | |
| TP 3 | 9.77 | 105.79 | | | |
| 254.7 | | | 9.44 | 96.36 | |
| 266.7 | | | 9.82 | 95.98 | |
| 274.9 | | | 9.49 | 96.30 | |
| 289.3 | | | 7.16 | 98.64 | |
| 295.0 | | | 6.95 | 98.84 | |
| 302.3 | | | 5.17 | 100.62 | |
| 312.8 | | | 3.21 | 102.58 | |
| 312.8 | | | 2.35 | 103.44 | TOP OF STAKE |
| TP 4 | | | 7.63 | 98.16 | |
| TP 4 | 6.66 | 104.82 | | | |
| TP 5 | | | 14.40 | 90.42 | |
| TP 5 | 11.11 | 101.53 | | | |
| TBM 1 | | | 1.53 | 100.00 | |

```
WATERSHED:  WS-6

DATE:  24 JUN 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  3

STATION      BS        HI          FS     ELEVATION                  REMARKS
 TBM 1      1.35     101.35         -
 STA 1                            9.10      100.00     STA 0+00, TOP OF STEEL STAKE
 STA 2                            3.80       92.26     HIGH WATER MARK, NE BANK
 STA 3                            4.10       97.56     HIGH WATER MARK,  FLOOD PLAIN, SW SIDE
 STA 4                            4.20       97.26     HIGH WATER MARK,  FLOOD PLAIN, SW SIDE
 STA 5                            3.90       97.16     HIGH WATER MARK,  FLOOD PLAIN, SW SIDE
 STA 6                            7.70       97.46     HIGH WATER MARK,  FLOOD PLAIN, SW SIDE
 STA 7                            8.20       93.66     HIGH WATER MARK, SW BANK, IN BRUSH
 TBM 1                            1.35       93.16     HIGH WATER MARK, NE BANK
                                            100.00
```

```
WATERSHED:  WS-6

DATE:  10 JUN 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  3

STATION      BS        HI         FS     ELEVATION                REMARKS

 TBM 1      1.32     101.32               100.00
  TP 1                          10.54      90.78
  TP 1      6.31      97.09
   0.0                           7.4       89.7     CROSS-SECTION STATION 1+46.8
 100.0                           5.9       91.2
 200.0                           3.7       93.4
 300.0                           2.3       94.8
 400.0                           1.5       95.6
  TP 2                           6.18      90.92
  TP 2     13.20     104.12
  TP 3                           8.11      96.02
  TP 3      9.77     105.79
  TP 4                           7.63      98.16
  TP 4      6.66     104.82
  TP 5                          14.40      90.42
  TP 5     11.11     101.53
 TBM 1                           1.53     100.00
```

```
WATERSHED:  WS-6

DATE:  11 JUN 1979

DATA:   CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  4

STATION       BS          HI           FS    ELEVATION                    REMARKS

 TBM 1       3.94       103.94                 100.00
   0.0                                4.48      99.46
  17.6                                4.80      99.14
  36.4                                4.60      99.34
  64.7                                4.69      99.26
  70.8                                5.23      98.72
  75.3                                7.08      96.86
  74.0                                6.69      97.26        1968 HIGH WATER MARK
 STA 1                                6.77      97.18        1968 HIGH WATER MARK - STAKE
  81.6                                8.40      95.54
  95.7                                9.11      94.84
 100.0                                9.58      94.36
 105.9                                9.63      94.32
 117.5                               11.20      92.74
 120.5                               11.10      92.84        1978 HIGH WATER
 STA 2                               10.99      93.06        1978 HIGH WATER - STAKE
 128.1                               11.64      92.30        DEBRIS LINE ON ROAD DOWNSTREAM FROM LINE
 STA 3                               11.69      92.26        DEBRIS LINE ON ROAD DOWNSTREAM FROM LINE
 STA 4                               11.65      92.30        DEBRIS LINE ON ROAD DOWNSTREAM FROM LINE
 136.0                               12.42      91.52
 138.5                               12.68      91.26
 143.3                               13.36      90.58
 146.1                               15.31      88.64
 147.7                               15.37      88.58
 152.4                               14.54      89.40
 154.6                               14.83      89.12
 151.1                               14.79      89.16
 172.1                               13.86      90.08
 176.0                               13.89      90.06
 191.7                               13.67      90.28
 200.0                               15.87      88.08
 206.5                               16.05      87.90
 234.0                               15.48      88.46
 237.6                               14.74      89.20
 239.7                               14.45      89.50
 244.2                               13.10      90.84
```

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 4 CONTINUED

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| 278.4 | | | 7.59 | 96.36 | |
| 287.4 | | | 7.23 | 96.72 | |
| 300.0 | | | 7.23 | 96.72 | |
| 308.4 | | | 6.99 | 96.96 | |
| 308.4 | | | 6.55 | 97.40 | TOP OF 1/2 IN. IRON PIN |
| TP 1 | | | 13.61 | 90.34 | |
| TP 1 | 8.13 | 98.47 | | | |
| TP 2 | | | 1.40 | 97.08 | |
| TP 2 | 7.42 | 104.50 | | | |
| TBM 1 | | | 4.47 | 100.03 | |

```
WATERSHED:  WS-6

DATE:  24 JUN 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  4

STATION     BS        HI          FS    ELEVATION                 REMARKS

 TBM 1      3.78      103.78              100.00     STA 0+00. TOP OF STEEL STAKE
  TP 1                            9.17     94.62
  TP 1      8.22      102.84
 308.4                            5.89     96.96     GROUND
 338.6                            7.18     95.66
 348.4                            7.06     95.78
 351.8                            7.39     95.46
 369.7                            7.59     95.26
 375.7                            7.27     95.58
 379.0                            6.74     96.10
 384.4                            5.94     96.90        TOP OF CONFINING FLOOD PLAIN TERRACE
ELEVATION     =   98.4    97.9
DIST FM CENTR =   14.0L   10.0L
 388.0                            6.36     96.48
 392.6                            6.78     96.06     SW EDGE OF ROAD
 410.6                            6.08     96.76     NE EDGE OF ROAD
 414.3                            4.88     97.96
 420.2                            5.20     97.64
 424.9                            4.79     98.06     GROUND
 424.9                            4.04     98.80     TOP OF STEEL STAKE
  TP 2                            3.13     99.72
  TP 2      5.79      105.51
  TP 3                            6.81     98.70
  TP 3      6.34      105.04
 TBM 1                            5.01    100.03
```

WATERSHED: WS-6

DATE: 11 JUN 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 4

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 3.94 | 103.94 | | 100.00 | |
| TP 1 | | | 13.61 | 90.34 | |
| TP 1 | 8.13 | 98.47 | | | |
| 0.0 | | | 10.7 | 87.8 | CROSS-SECTION STATION 2+06.9 |
| 100.0 | | | 10.2 | 88.3 | |
| 200.0 | | | 9.5 | 89.0 | |
| 300.0 | | | 8.0 | 90.5 | |
| 400.0 | | | 5.9 | 92.6 | |
| 500.0 | | | 5.0 | 93.5 | |
| TP 2 | | | 1.40 | 97.08 | |
| TP 2 | 7.42 | 104.50 | | | |
| TBM 1 | | | 4.47 | 100.03 | |

WATERSHED: WS-7

DATE: 21 JUN 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 1

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 7.08 | 107.08 | | 100.00 | STA 0+00, TOP OF STEEL STAKE IN ROCK |
| 0.0 | | | 7.61 | 99.48 | CARIN SUPPORTING BOUNDARY MARKER |
| 23.1 | | | 9.35 | 97.74 | |
| 37.6 | | | 9.97 | 97.12 | |
| 44.5 | | | 10.40 | 96.68 | |
| 46.0 | | | 10.67 | 96.42 | |
| 50.0 | | | 10.79 | 96.30 | |
| 60.8 | | | 11.36 | 95.72 | |
| 66.2 | | | 11.61 | 95.48 | |
| 71.2 | | | 12.83 | 94.26 | |
| 74.3 | | | 13.75 | 93.34 | |
| 77.6 | | | 15.07 | 92.02 | |
| 81.3 | | | 16.82 | 90.26 | |
| 84.6 | | | 18.13 | 88.96 | ON ROCK, TOP OF VERTICAL WALL |
| 88.3 | | | 24.22 | 82.86 | ON BANK BELOW BASE OF VERT ROCK WALL |
| TP 1 | | | 18.50 | 88.58 | |
| TP 1 | 15.78 | 104.36 | | | |
| 91.5 | | | 23.43 | 80.94 | |
| 100.0 | | | 24.53 | 79.84 | |
| 103.5 | | | 24.87 | 79.50 | |
| 105.9 | | | 24.50 | 79.86 | |
| 108.8 | | | 24.09 | 80.28 | OFF LINE DOWNSTREAM 0.2 FT |
| STA 1 | | | 23.70 | 80.66 | HIGH WATER MARK, ABOUT STA 1+10 |
| 111.7 | | | 23.44 | 80.92 | TREE TRUNK |
| 114.4 | | | 21.57 | 82.80 | |
| 122.3 | | | 17.54 | 86.82 | |
| 122.7 | | | 15.77 | 88.60 | ROCK LEDGE |
| 132.3 | | | 9.35 | 95.02 | |
| 135.3 | | | 6.25 | 98.12 | TOP OF SEPARATING RIDGE, 1.5 FT WIDE |
| 138.1 | | | 6.39 | 97.98 | |
| 141.2 | | | 7.02 | 97.34 | |
| 142.0 | | | 7.91 | 96.46 | |
| 147.6 | | | 9.43 | 94.94 | |
| 151.4 | | | 11.48 | 92.88 | |
| 152.7 | | | 12.69 | 91.68 | |
| 155.4 | | | 13.72 | 90.64 | |

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 1 CONTINUED

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| 158.5 | | | 15.06 | 89.30 | |
| 162.3 | | | 16.11 | 88.26 | |
| 165.4 | | | 16.14 | 88.22 | |
| 166.5 | | | 15.40 | 88.96 | HIGH WATER MARK ? |
| 166.8 | | | 15.25 | 89.12 | |
| 168.4 | | | 14.51 | 89.86 | |
| 191.6 | | | 4.22 | 100.14 | |
| 199.1 | | | 2.72 | 101.64 | |
| 200.1 | | | 1.18 | 103.18 | |
| TP 2 | | | 3.53 | 100.84 | |
| TP 2 | 5.05 | 105.39 | | | |
| 207.1 | | | 1.66 | 104.24 | |
| 207.1 | | | 0.86 | 105.04 | TOP OF STEEL STAKE |
| TBM 1 | | | 5.92 | 99.97 | |

```
WATERSHED:  WS-7

DATE:  21 JUN 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  1

STATION      BS        HI        FS    ELEVATION                    REMARKS

 TBM 1      5.92     105.92             100.00
  50.0                         24.2      81.7     SOUTH (MAJOR) CHANNEL
 100.0                         21.7      84.2     SOUTH (MAJOR) CHANNEL
 150.0                         20.1      85.8     SOUTH (MAJOR) CHANNEL
   0.0                         17.8      88.1     NORTH CHANNEL
  50.0                         14.0      91.9     NORTH CHANNEL
 100.0                         11.6      94.3     NORTH CHANNEL
  TP 1                          6.53     99.40
  TP 1      4.87     104.27
   0.0                         24.7      79.6     S. CHANNEL   X-SECT STA 1+03.5
 TBM 1                          4.24    100.03
```

```
WATERSHED:  WS-7

DATE:  22 JUN 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  2

STATION      BS         HI          FS    ELEVATION                     REMARKS

 TBM 1      2.44      102.44                100.00     TOP OF STEEL STAKE, STA 0+00
   0.0                              2.80     99.64
   5.2                              2.92     99.52
  19.3                              4.13     98.32
  29.3                              8.97     93.48
  34.6                             11.35     90.60     TRAIL
  37.5                             12.82     89.62
  46.9                             16.98     85.46
  50.3                             18.32     84.12
  53.7                             20.51     81.94
  56.8                             22.05     80.40
  58.9                             22.20     80.24
 STA 1                             23.10     79.34     HIGH WATER MARK, ABOUT STA 60.4
  60.4                             23.38     79.06
  63.9                             23.42     79.02
  68.0                             24.54     77.90     LOWEST POINT
  73.1                             28.48     73.96
  75.2                             22.48     79.96
  76.8                             22.40     80.04
  79.9                             21.92     80.52
  81.2                             21.57     80.88     HIGH WATER MARK
  85.9                             20.41     82.04
  88.3                             18.77     83.68
  92.1                             17.88     84.56
 100.0                             17.39     84.56
 109.7                             17.43     85.02
 112.8                             15.70     86.74     TOP OF ROCK
 113.4                             16.23     86.22     BEHIND ROCK
 118.2                             14.65     87.80
 123.2                             13.62     88.82
 125.7                             13.47     88.98
 131.4                             13.25     89.20
 136.5                             11.62     90.82
 137.5                             10.79     91.66     TOP OF ROCK
 139.0                             10.96     91.48
 144.2                             10.38     92.06
```

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 2 CONTINUED

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| 148.7 | | | 10.42 | 92.02 | |
| 159.5 | | | 10.24 | 92.20 | |
| 159.9 | | | 9.22 | 93.22 | |
| TBM 1 | | | 2.44 | 100.00 | TOP OF STEEL STAKE |

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WATERSHED:  WS-7

DATE:  22 JUN 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  2

STATION     BS      HI        FS    ELEVATION              REMARKS

 TBM 2     6.77   106.77             100.00    TOP OF STEEL STAKE. X-SECT STA 1+59.9
   0.0                       21.9     84.9
  50.0                       19.7     87.1
 100.0                       17.3     89.5
 125.0                       16.1     90.7
 150.0                       14.2     92.6
 200.0                       12.5     94.3
 250.0                        9.9     96.9
 TBM 2                        6.77   100.00
```

WATERSHED: WS-7

DATE: 22 JUN 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 3

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 7.00 | 107.00 |  | 100.00 | TOP OF STEEL STAKE, STA 0+00 |
| 0.0 |  |  | 7.48 | 99.52 |  |
| 6.3 |  |  | 8.50 | 98.50 | GAME TRAIL |
| 15.4 |  |  | 6.98 | 100.02 |  |
| 21.3 |  |  | 10.59 | 96.42 |  |
| 27.2 |  |  | 11.01 | 96.00 |  |
| 30.0 |  |  | 10.84 | 96.16 |  |
| 34.0 |  |  | 10.55 | 96.46 |  |
| 36.8 |  |  | 10.25 | 96.76 |  |
| 40.6 |  |  | 9.88 | 97.12 |  |
| 42.8 |  |  | 9.87 | 97.14 |  |
| 47.6 |  |  | 9.90 | 97.10 |  |
| 51.3 |  |  | 9.97 | 97.04 |  |
| 55.7 |  |  | 10.57 | 96.44 |  |
| 58.2 |  |  | 11.32 | 95.68 |  |
| 73.8 |  |  | 19.70 | 87.30 |  |
| 77.1 |  |  | 20.14 | 86.86 |  |
| 79.4 |  |  | 19.98 | 87.02 |  |
| 80.7 |  |  | 20.26 | 86.74 |  |
| 82.6 |  |  | 20.93 | 86.08 |  |
| 85.5 |  |  | 20.53 | 86.48 |  |
| 86.5 |  |  | 20.16 | 86.84 |  |
| 91.8 |  |  | 20.40 | 86.60 |  |
| 94.1 |  |  | 20.81 | 86.20 |  |
| 96.1 |  |  | 21.16 | 85.84 |  |
| 99.3 |  |  | 21.21 | 85.80 |  |
| 103.1 |  |  | 20.93 | 86.08 |  |
| 104.4 |  |  | 20.68 | 86.32 |  |
| 106.2 |  |  | 20.93 | 86.08 |  |
| 108.2 |  |  | 20.60 | 86.40 |  |
| 110.5 |  |  | 20.32 | 86.68 |  |
| 112.3 |  |  | 19.65 | 87.36 |  |
| 125.6 |  |  | 15.94 | 91.06 |  |
| 131.6 |  |  | 14.41 | 92.60 |  |
| 135.7 |  |  | 13.08 | 93.92 |  |
| 139.4 |  |  | 12.49 | 94.52 |  |

```
DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  3 CONTINUED

STATION      BS          HI           FS    ELEVATION
                                                                   REMARKS
 146.2                               11.98     95.02
 152.4                               11.60     95.40
 158.6                               11.27     95.74
 164.9                               11.08     95.92
 172.2                               11.08     95.92
 172.2                               10.28     96.72
 TBM 1                                7.00    100.00       TOP OF STEEL STAKE
```

```
WATERSHED:  WS-7

DATE:  22 JUN 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  3

STATION      BS        HI          FS    FLEVATION                    REMARKS

 TBM 1      7.00     107.00               100.00
 STA 1                           20.50     86.50    HIGH WATER MARK
   0.0                           21.2      85.8
 101.0                           18.2      88.8
 200.0                           16.1      90.9
 TBM 1                            7.00    100.00
```

```
WATERSHED:  888D

DATE:  23 JUN 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  1

STATION      BS        HI         FS    ELEVATION                REMARKS

 TBM 1     0.09      100.09             100.00    TOP OF STEEL STAKE, STA 0+00
   0.0                         1.03      99.06
  11.4                         3.27      96.82
  17.0                         3.58      96.52
  20.4                         4.11      95.98
  32.0                         4.67      95.42
  42.3                         5.11      94.98
  54.7                         5.24      94.86
  66.0                         5.41      94.68
  77.2                         6.03      94.06
  82.4                         6.60      93.50
  87.2                         7.07      93.02
  90.8                         8.07      92.02
  93.4                         9.13      90.96
  96.5                        10.94      89.16
  98.3                        11.77      88.32
  98.7                        12.44      87.66
 101.0                        14.01      86.08
 103.0                        15.53      84.56
 105.2                        16.61      83.48
 108.4                        18.06      82.04
 STA 1                        19.80      80.30    HIGH WATER MARK
 112.1                        19.98      80.12
 113.7                        20.64      79.46
 117.6                        21.31      78.78
 119.9                        21.13      78.96
 122.1                        21.27      78.82
 124.9                        20.61      79.48
 126.1                        20.23      79.86
 127.8                        19.30      80.30    HIGH WATER MARK
 130.0                        18.73      81.36
 131.8                        17.70      82.40
 133.4                        17.00      83.10
 135.7                        15.57      84.52
 137.9                        14.81      85.28
 139.9                        11.34      88.26
```

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 1 CONTINUED

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| 142.5 | | | 10.50 | 89.60 | |
| 145.1 | | | 9.57 | 90.52 | |
| 147.7 | | | 8.38 | 91.72 | |
| 150.2 | | | 7.27 | 92.82 | |
| 150.7 | | | 7.03 | 93.06 | |
| 152.5 | | | 6.78 | 93.32 | |
| 154.5 | | | 6.62 | 93.48 | |
| 156.8 | | | 6.21 | 93.88 | |
| 157.5 | | | 6.02 | 94.08 | |
| 160.9 | | | 5.74 | 94.36 | |
| 166.4 | | | 4.92 | 95.18 | |
| 170.3 | | | 4.69 | 95.40 | |
| 173.3 | | | 3.92 | 96.18 | |
| 175.7 | | | 3.79 | 96.30 | |
| 177.3 | | | 3.95 | 96.14 | |
| 178.1 | | | 4.49 | 95.60 | |
| 179.6 | | | 4.42 | 95.68 | |
| 181.5 | | | 4.56 | 95.54 | |
| 184.1 | | | 3.85 | 96.24 | |
| 187.6 | | | 3.31 | 96.78 | |
| 191.9 | | | 2.84 | 97.26 | |
| 196.0 | | | 2.39 | 97.70 | |
| 196.0 | | | 2.05 | 98.04 | TOP OF STEEL STAKE |
| TBM 1 | | | 0.09 | 100.00 | |

```
WATERSHED:   888D

DATE:  23 JUN 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  1

STATION      BS        HI         FS    FLEVATION                    REMARKS

  TBM 1      0.09     100.09               100.00
    0.0                          21.3       78.8
   50.0                          20.9       79.2
  100.0                          18.9       81.2
  150.0                          16.9       83.2
  200.0                          16.1       84.0
  250.0                          14.9       85.2
  TBM 1                           0.09     100.00
```

```
WATERSHED:  8B8D

DATE:  23 JUN 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  2

STATION       BS        HI          FS    ELEVATION                 REMARKS

 TBM 1       1.52     101.52               100.00     TOP OF STEEL STAKE. STA 0+00
   0.0                             2.03     99.50
  12.1                             8.23     93.30
  21.4                            12.65     88.88
 STA 1                            14.63     86.90     HIGH WATER MARK
  26.8                            15.06     86.46
  28.8                            15.90     85.62
  31.0                            16.70     84.82
  33.0                            16.74     84.78
  34.4                            16.51     85.02
  35.7                            15.65     85.88
  37.4                            14.92     86.60
  39.5                            14.44     87.08
  41.6                            14.38     87.14
  43.7                            14.44     87.08
  61.7                            13.00     88.52
  70.9                            12.31     89.22
  77.6                            12.30     89.22
  89.4                            12.19     89.34
 102.7                            11.20     90.32
 116.6                            10.27     91.26
 135.8                             8.98     92.54
 159.4                             7.27     94.26
 179.0                             4.59     96.94
 198.4                             1.57     99.96
 198.4                             0.76    100.76     TOP OF STEEL STAKE
 TBM 1                             1.52    100.00
```

WATERSHED: 888D

DATE: 23 JUN 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 2

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 1.52 | 101.52 | | 100.00 | |
| 0.0 | | | 16.8 | 84.7 | |
| 50.0 | | | 14.8 | 86.7 | |
| 100.0 | | | 13.2 | 88.3 | |
| 150.0 | | | 11.4 | 90.1 | |
| TP 1 | | | 5.75 | 95.78 | |
| TP 1 | 8.32 | 104.10 | | | |
| 200.0 | | | 12.9 | 91.2 | |
| 250.0 | | | 10.5 | 93.6 | |
| TBM 1 | | | 4.08 | 100.02 | |

WATERSHED: 8B8D

DATE: 23 JUN 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 3

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 4.76 | 104.76 | | 100.00 | TOP OF STEEL STAKE. STA 0+00 |
| 0.0 | | | 6.69 | 98.08 | |
| 4.0 | | | 7.28 | 97.48 | |
| 5.1 | | | 7.39 | 97.38 | |
| 6.2 | | | 7.95 | 96.82 | |
| 7.6 | | | 8.09 | 96.68 | |
| 10.2 | | | 9.37 | 95.40 | |
| 12.6 | | | 10.02 | 94.74 | |
| 13.3 | | | 10.59 | 94.18 | |
| 16.8 | | | 11.52 | 93.24 | |
| 18.7 | | | 12.19 | 92.58 | |
| 21.7 | | | 13.08 | 91.68 | |
| 25.3 | | | 13.28 | 91.48 | |
| 28.5 | | | 13.84 | 90.92 | |
| 30.4 | | | 14.12 | 90.64 | |
| 31.2 | | | 14.02 | 90.74 | |
| 32.7 | | | 14.43 | 90.34 | |
| 33.9 | | | 14.52 | 90.24 | |
| 35.5 | | | 14.29 | 90.48 | |
| 36.6 | | | 13.44 | 91.32 | |
| 39.0 | | | 13.22 | 91.54 | |
| 40.5 | | | 13.00 | 91.76 | |
| 43.6 | | | 12.51 | 92.26 | HIGH WATER MARK |
| 46.5 | | | 12.66 | 92.10 | |
| 52.4 | | | 12.50 | 92.26 | |
| 57.4 | | | 12.23 | 92.54 | |
| 60.8 | | | 11.72 | 93.04 | |
| 64.9 | | | 11.10 | 93.66 | |
| 68.6 | | | 10.04 | 94.72 | |
| 75.1 | | | 9.11 | 95.66 | |
| 80.7 | | | 8.41 | 96.36 | |
| 84.2 | | | 7.86 | 96.90 | |
| 88.1 | | | 7.55 | 97.22 | |
| 92.4 | | | 7.21 | 97.56 | |
| 92.4 | | | 5.30 | 99.46 | TOP OF STEEL STAKE |
| TBM 1 | | | 4.77 | 99.99 | |

WATERSHED: 8B8D

DATE: 24 JUN 1979

DATA: CHANNEL PROFILE GOING UPSTREAM FROM LOCATION 3

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 4.53 | 104.53 | | 100.00 | TOP OF STEEL STAKE |
| 92.4 | | | 5.1 | 99.5 | TOP OF STEEL STAKE |
| STA 1 | | | 12.34 | 92.20 | HIGH WATER MARK |
| 0.0 | | | 14.2 | 90.3 | |
| 50.0 | | | 12.8 | 91.7 | |
| 100.0 | | | 12.1 | 92.4 | |
| TP 1 | | | 7.23 | 97.30 | |
| TP 1 | 11.30 | 108.60 | | | |
| 150.0 | | | 13.9 | 94.7 | |
| 200.0 | | | 12.5 | 96.1 | |
| 250.0 | | | 10.5 | 98.1 | |
| TBM 1 | | | 8.59 | 100.01 | |
| TBM 1 | 4.84 | 104.85 | | | |
| 0.0 | | | 4.8 | 100.0 | |
| 0.0 | | | 5.5 | 99.3 | TOP OF NEW STEEL STAKE |
| 92.4 | | | 5.4 | 99.5 | |
| 92.4 | | | 6.3 | 98.6 | TOP OF NEW STEEL STAKE |

WATERSHED: BOWL

DATE: 24 JUL 1979

DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 1

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 3.14 | 103.14 | | 100.00 | STA 0+00, TOP OF STEEL STAKE |
| 0.0 | | | 4.00 | 99.14 | GROUND |
| 15.7 | | | 4.35 | 98.80 | |
| 27.6 | | | 4.77 | 98.38 | |
| 32.2 | | | 5.43 | 97.72 | |
| 41.3 | | | 8.33 | 94.82 | |
| STA 1 | | | 3.20 | 99.94 | HIGH WATER DEBRIS |
| 45.6 | | | 8.62 | 94.52 | |
| 58.2 | | | 7.95 | 95.20 | |
| 64.4 | | | 5.29 | 97.86 | |
| 68.6 | | | 3.40 | 99.74 | GAME TRAIL |
| TP 1 | | | 7.22 | 95.92 | |
| TP 1 | 13.54 | 109.46 | | | |
| 71.4 | | | 9.90 | 99.56 | |
| 74.6 | | | 6.56 | 102.90 | |
| 77.5 | | | 4.30 | 105.16 | GROUND |
| 77.5 | | | 3.75 | 105.72 | TOP OF STEEL STAKE |
| TP 2 | | | 13.54 | 95.92 | |
| TP 2 | 7.09 | 103.01 | | | |
| TBM 1 | | | 3.01 | 100.00 | |
| TBM 1 | 3.01 | 103.01 | | | |
| -11.8 | | | 3.61 | 99.40 | TRAIL |
| TBM 1 | | | 3.01 | 100.00 | (STOPPED BY THUNDERSTORM) |
| TBM 1 | 2.58 | 102.58 | | | (BEGAN AFTER THUNDERSTORM) |
| -43.2 | | | 2.42 | 100.16 | |
| -66.2 | | | 2.18 | 100.40 | |
| TBM 1 | | | 2.58 | 100.00 | |

```
WATERSHED:  BOWL

DATE:  24 JUL 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  1

STATION      BS        HI        FS    ELEVATION                    REMARKS

 TBM 1      2.52     102.52              100.00
   0.0                            3.0      99.5     HIGH WATER DEBRIS
 105.5                            2.6      99.9     HIGH WATER DEBRIS
   0.0                            8.0      94.5     CHANNEL BOTTOM
 100.0                            3.0      99.5     CHANNEL BOTTOM
```

```
WATERSHED:  BOWL

DATE:  24 JUL 1979

DATA:  CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION  2

STATION       BS        HI         FS    ELEVATION                   REMARKS

 TBM 1       2.56     102.56             100.00      STA 0+00. TOP OF STEEL STAKE
   0.0                           3.44     99.12      GROUND
  14.5                           4.11     98.46
 STA 1                           1.90    100.76      HIGH WATER DEBRIS
  24.5                           4.59     97.98
  29.8                           5.97     96.60
  38.5                           6.39     96.18
  40.0                           5.68     96.88      ROCK IN CHANNEL
  41.4                           6.18     96.38
  48.5                           5.15     97.42
  52.9                           4.45     98.12
  56.3                           3.39     99.18
  67.5                           2.74     99.82
  76.8                           2.52    100.04
  86.5                           2.25    100.32      GROUND
  86.5                           1.38    101.18      TOP OF STEEL STAKE
 111.6                           1.93    100.64
 114.3                           1.72    100.84      RISE NEXT TO TREE
 128.2                           1.82    100.74
 -10.4                           2.46    100.10
 -21.7                           1.20    101.36
 TBM 1                           2.56    100.00
```

```
WATERSHED:  BOWL

DATE:  24 JUL 1979

DATA:  CHANNEL PROFILE GOING UPSTREAM FROM LOCATION  2

STATION      BS        HI          FS    ELEVATION                 REMARKS

 TBM 1      3.52     103.52               100.00     (ROD READING ADJUSTED)
 100.0                            3.5     100.0      CHANNEL BOTTOM
 100.0                            1.4     102.1      HIGH WATER DEBRIS
 TBM 1                            3.52    100.00     (ROD READING ADJUSTED)
```

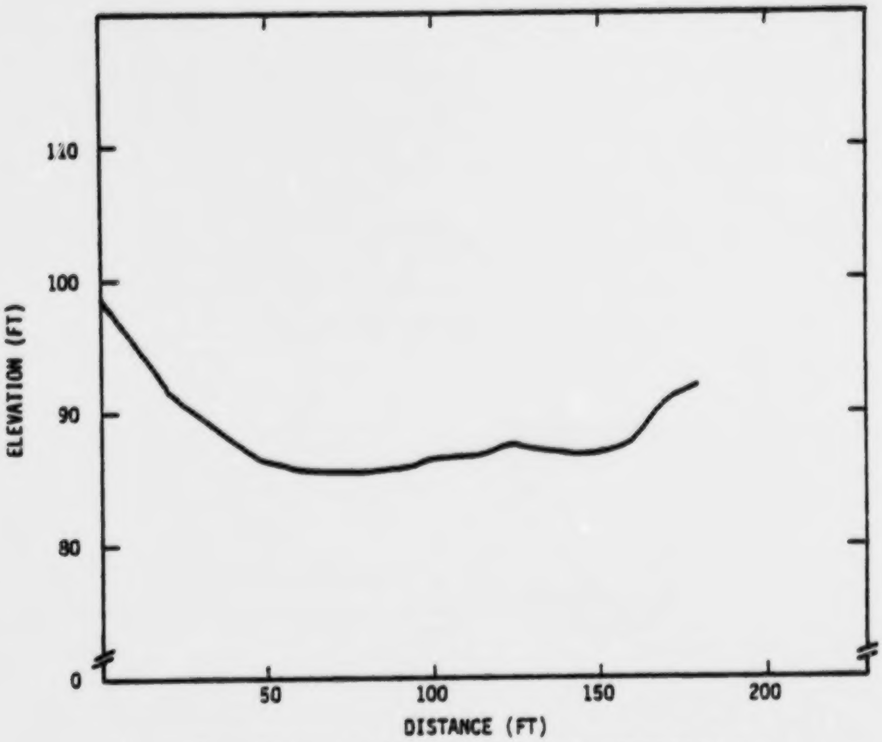
WATERSHED: BOWL

DATE: 24 JUL 1979

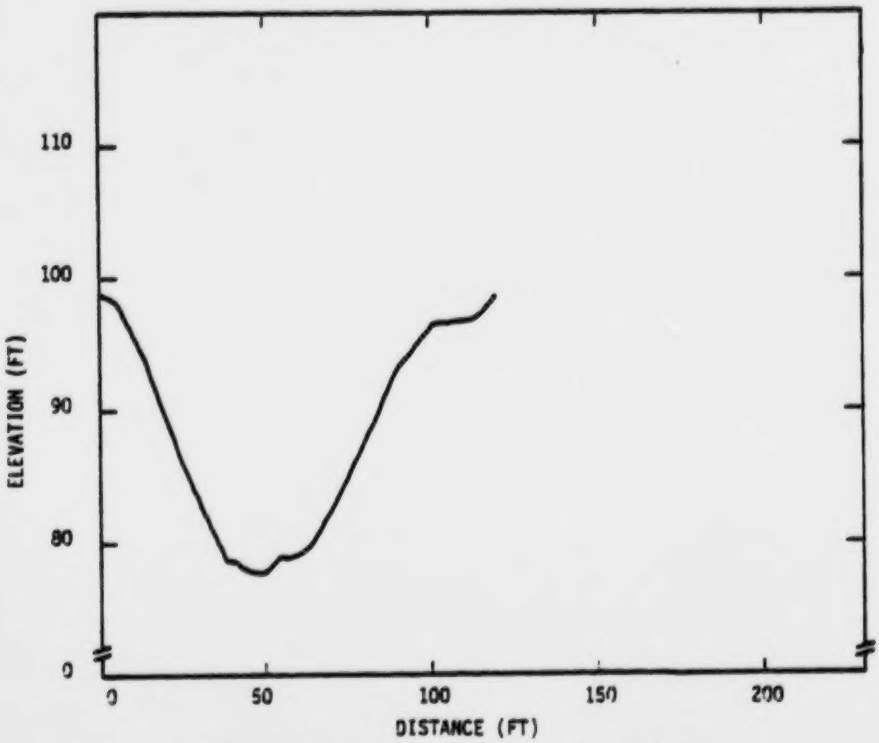
DATA: CHANNEL CROSS-SECTION (TRANSECT) AT LOCATION 3

| STATION | BS | HI | FS | ELEVATION | REMARKS |
|---|---|---|---|---|---|
| TBM 1 | 3.27 | 103.27 | | 100.00 | STA 0+00. TOP OF STEEL STAKE |
| 0.0 | | | 3.70 | 99.58 | GROUND |
| 7.2 | | | 4.21 | 99.06 | |
| 14.5 | | | 5.39 | 97.88 | |
| 16.6 | | | 5.33 | 97.94 | |
| 18.0 | | | 7.76 | 95.52 | |
| 21.1 | | | 8.28 | 95.00 | |
| 27.4 | | | 8.10 | 95.18 | |
| 31.4 | | | 7.74 | 95.54 | |
| 46.7 | | | 7.14 | 96.14 | |
| 49.5 | | | 6.87 | 96.40 | |
| 60.3 | | | 5.13 | 98.14 | |
| 70.9 | | | 4.27 | 99.00 | |
| 73.5 | | | 3.84 | 99.44 | |
| 74.7 | | | 2.19 | 101.08 | TOP OF ROCK |
| 76.0 | | | 3.63 | 99.64 | |
| 80.3 | | | 3.50 | 99.78 | GROUND |
| STA 1 | | | 7.20 | 96.08 | HIGH WATER DEBRIS ON DAM |
| 80.3 | | | 2.94 | 100.34 | TOP OF STEEL STAKE |
| TBM 1 | | | 3.27 | 100.00 | |
| STA 2 | | | 12.80 | 90.48 | CHANNEL BOTTOM NEAR LOCATION 2 |
| STA 3 | | | 13.30 | 89.98 | CHANNEL BOTTOM NEAR LOCATION 1 |

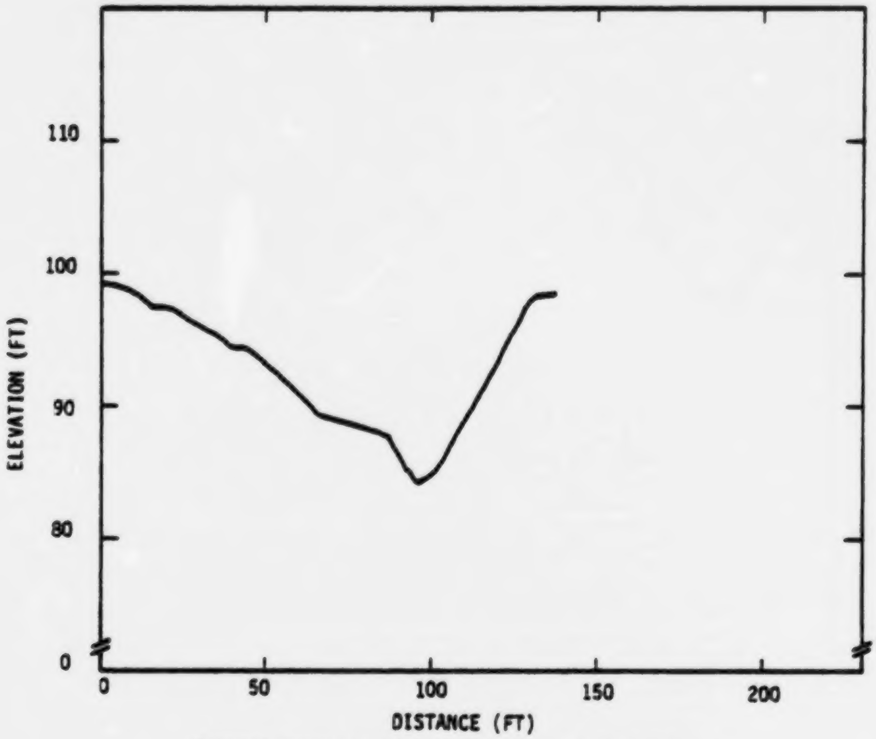
# APPENDIX E-- CHANNEL CROSS-SECTIONS.



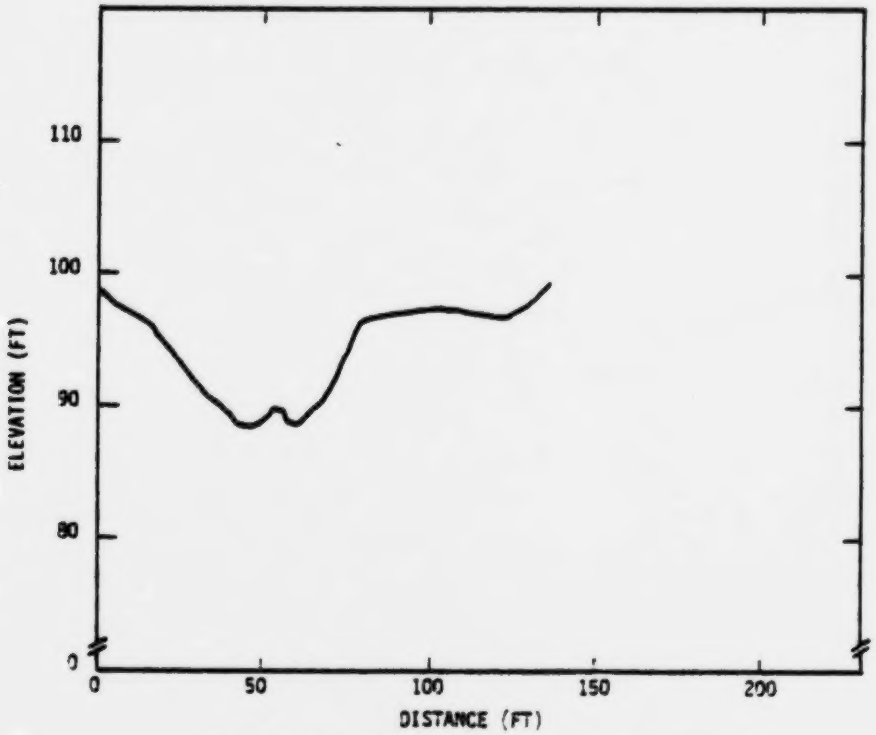
Channel cross-section at location 1, watershed 1.



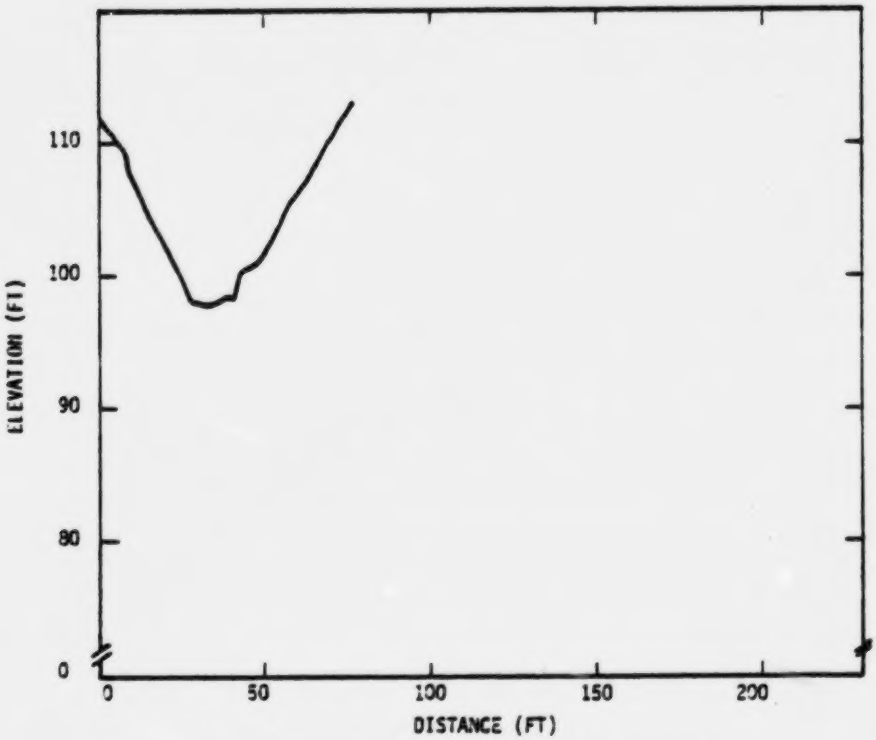
Channel cross-section at location 2, watershed 1.



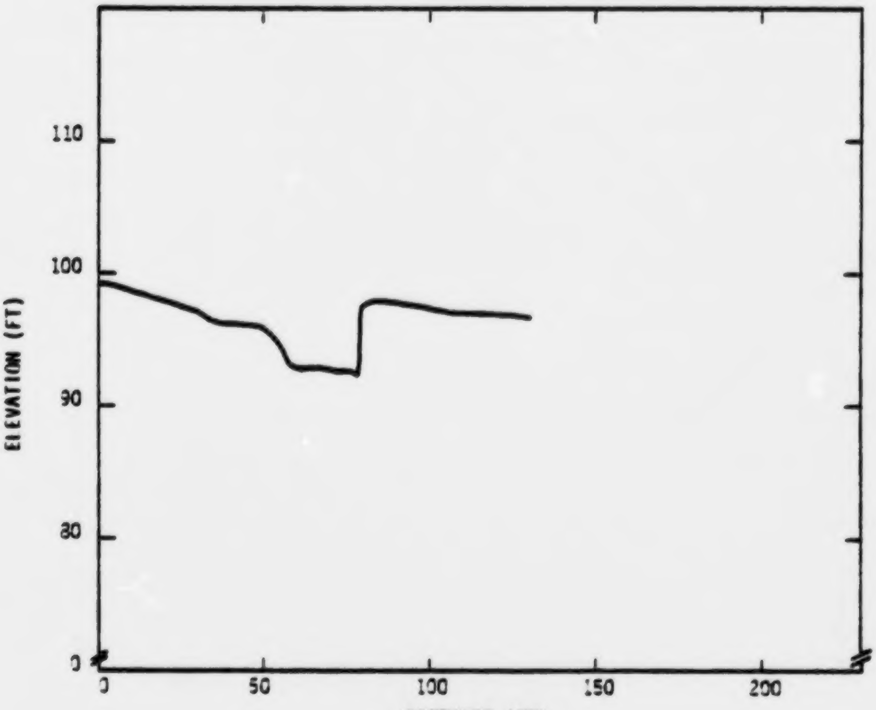
Channel cross-section at location 3, watershed 1.



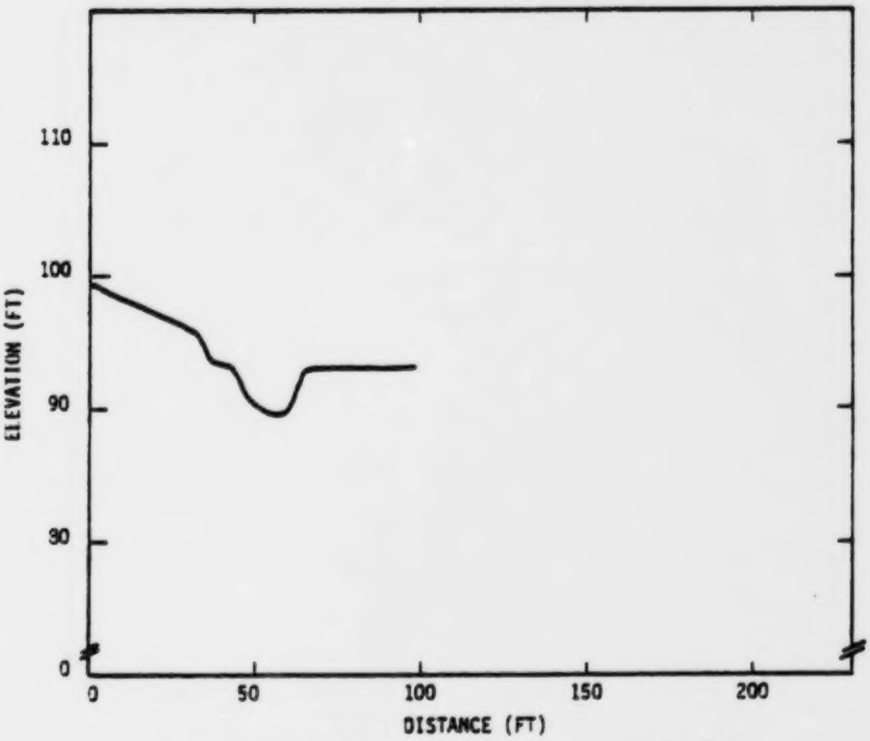
Channel cross-section at location 4, watershed 1.



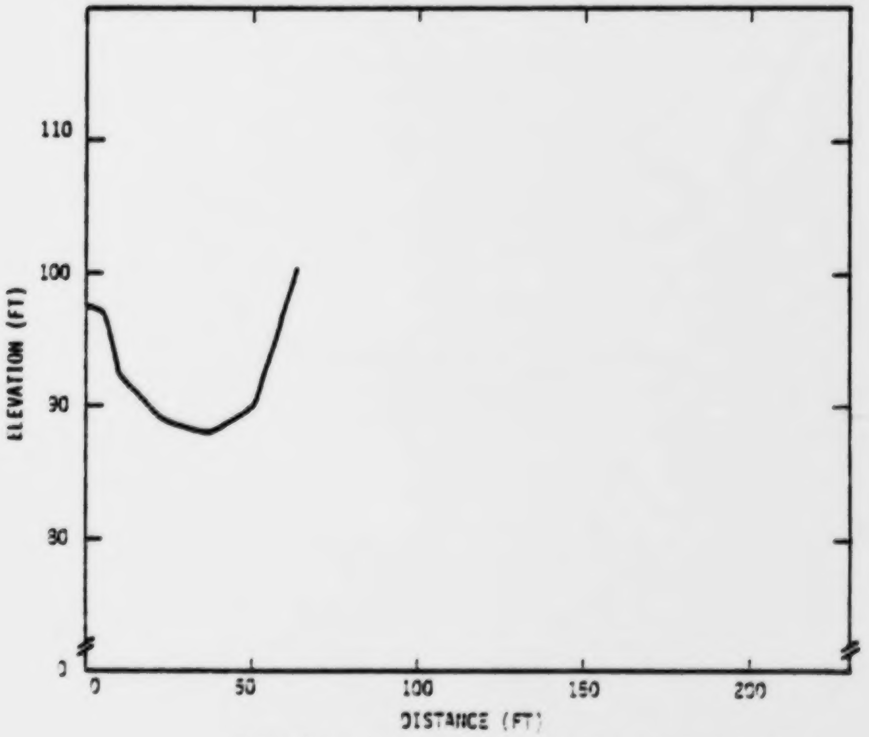
Channel cross-section at location 5, watershed 1.



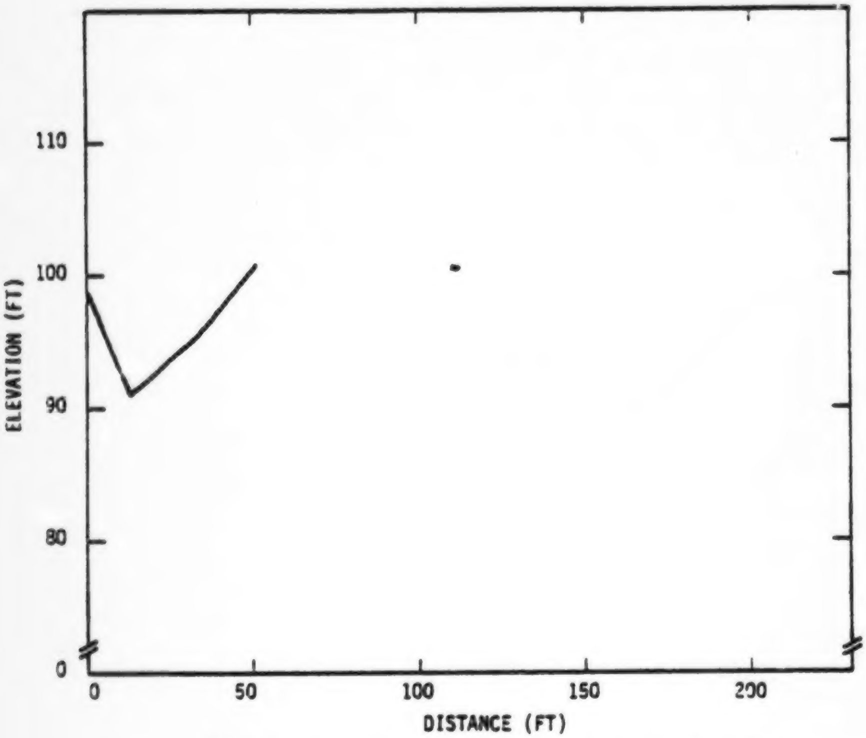
Channel cross-section at location 1, watershed 10A6.



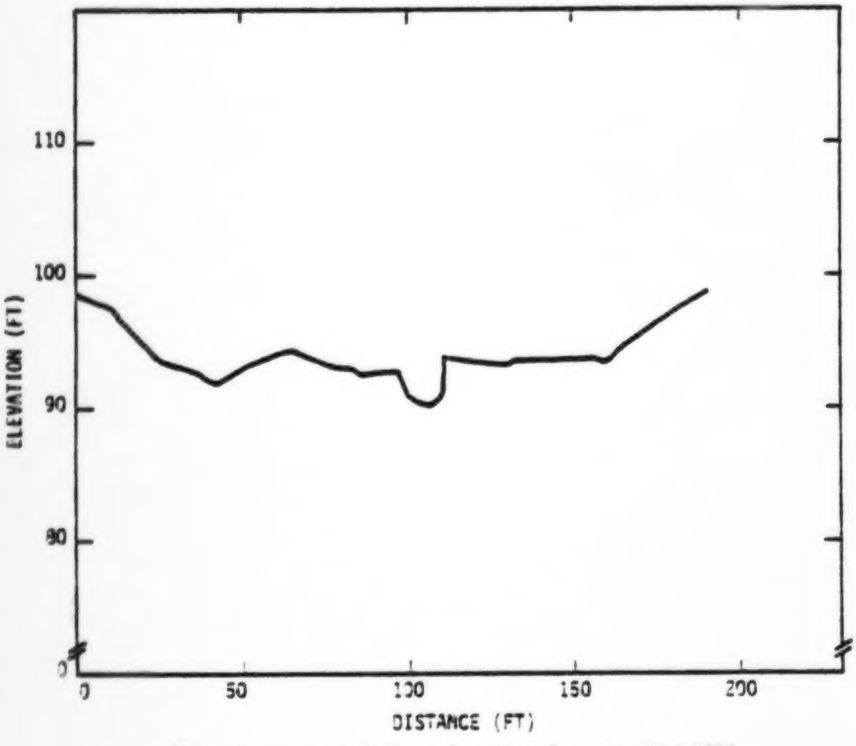
Channel cross-section at location 2, watershed 10A6.



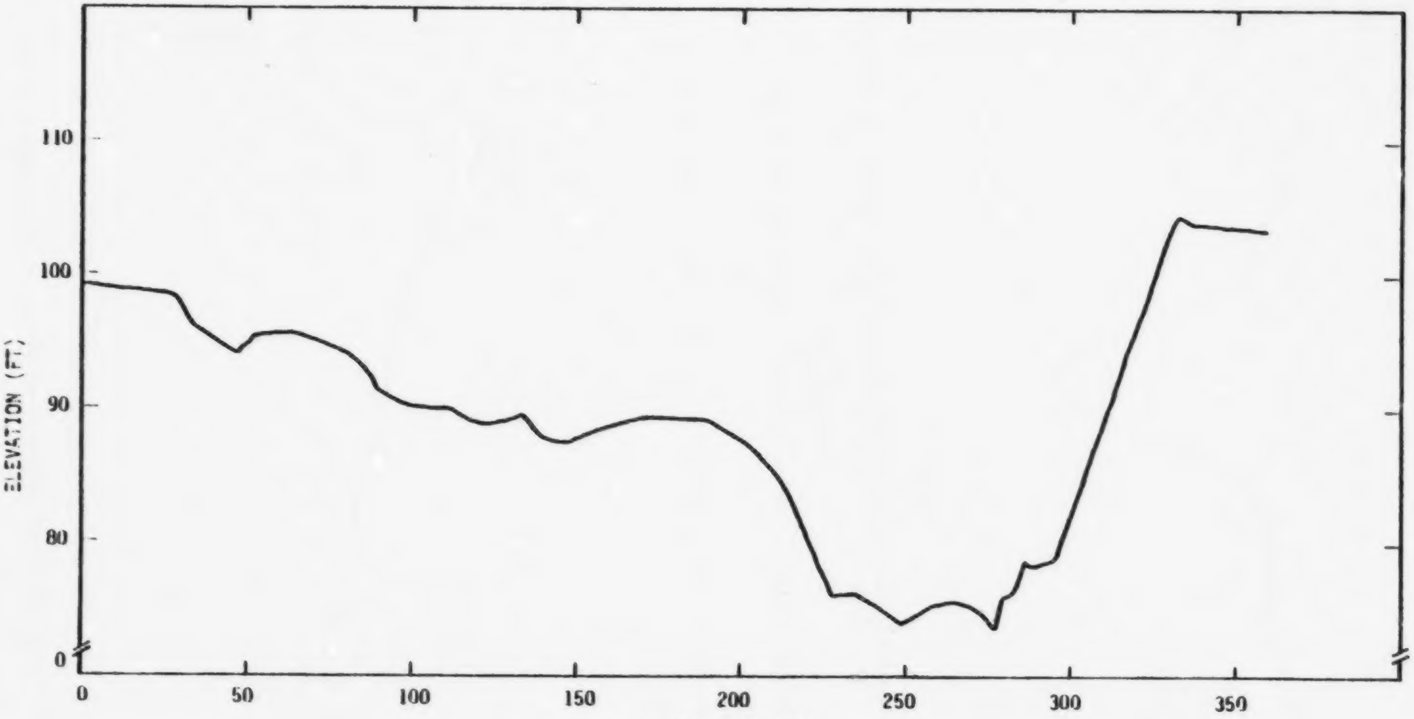
Channel cross-section at location 3, watershed 10A6.



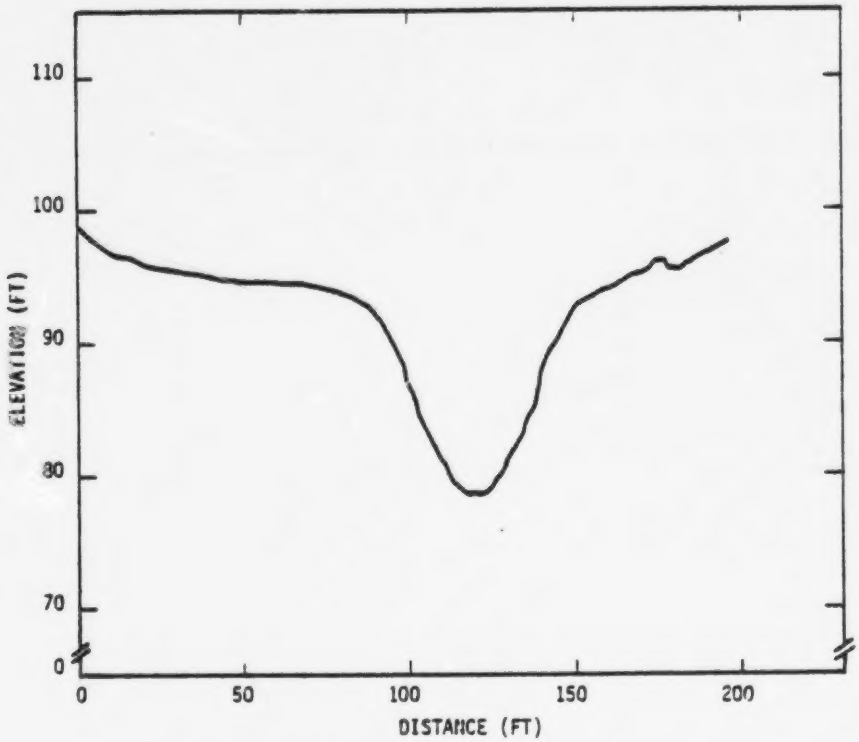
Channel cross-section at location 4, watershed 10A6.



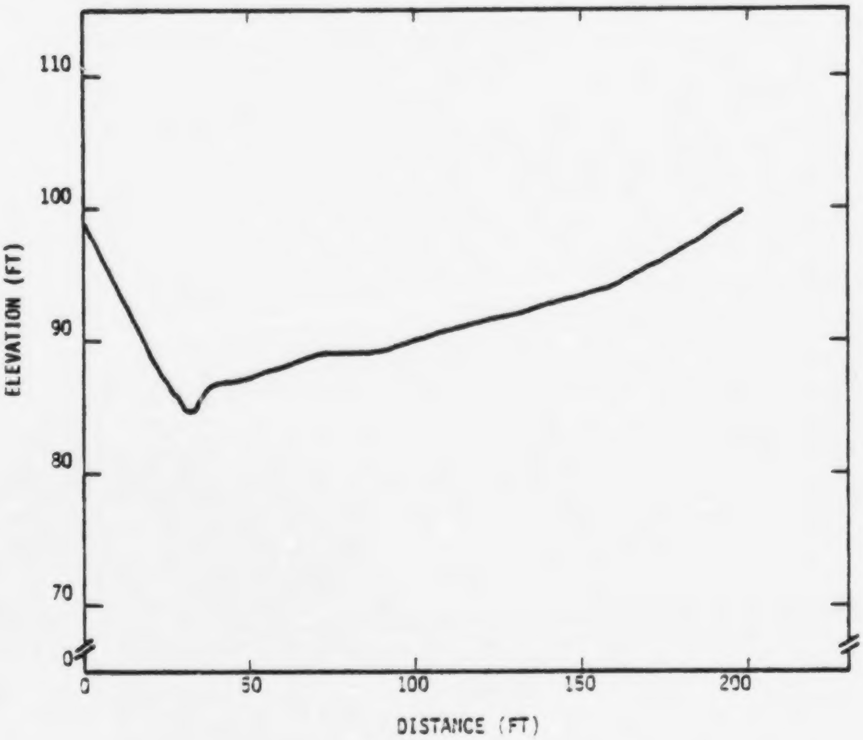
Channel cross-section at location 5, watershed 10A6.



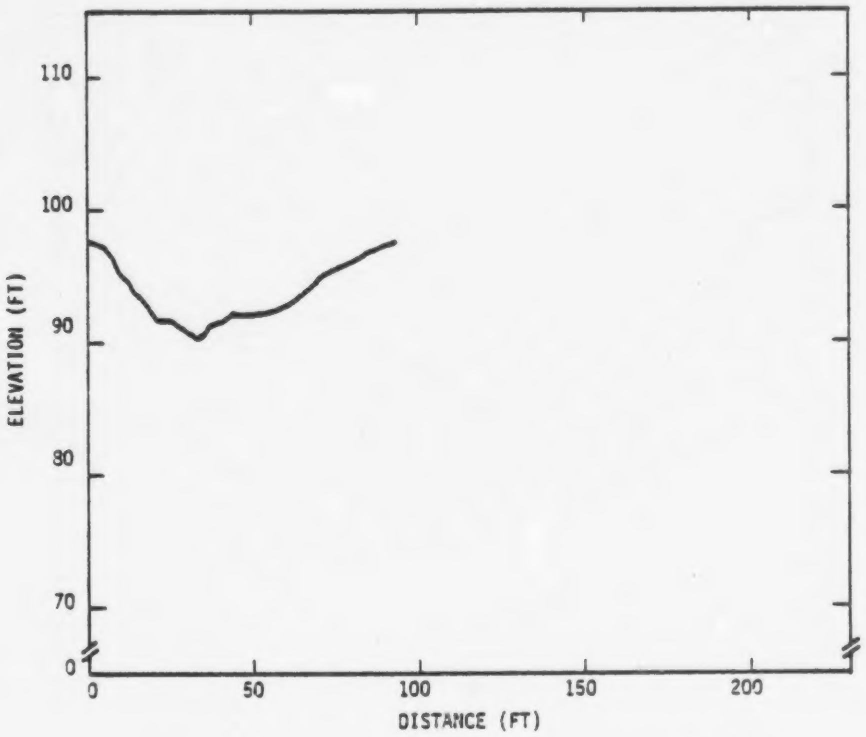
Channel cross-section at location 6, watershed 10A6.



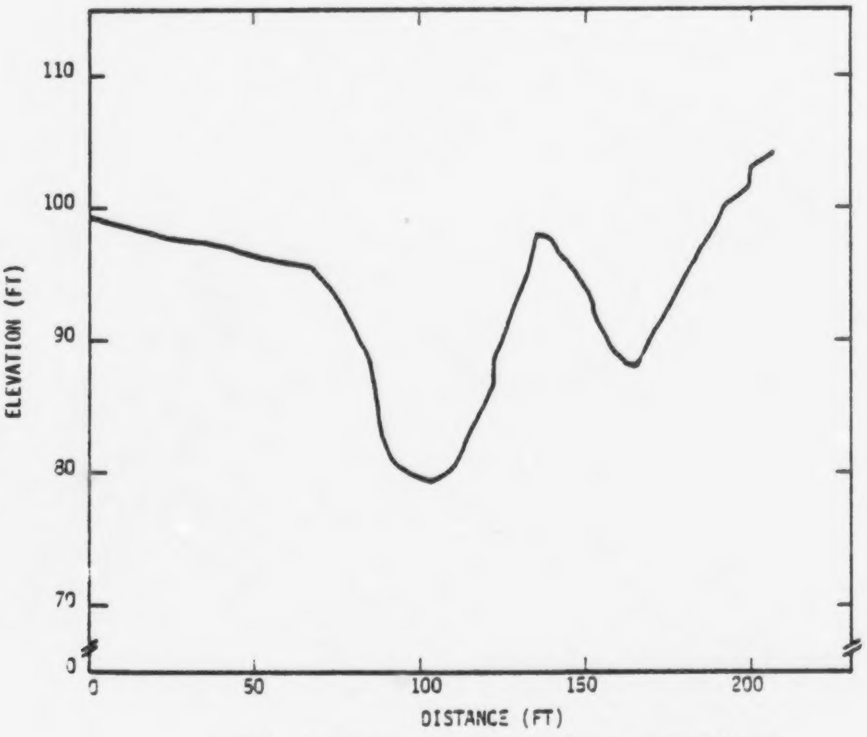
Channel cross-section at location 1, watersheds 8B and 8D.



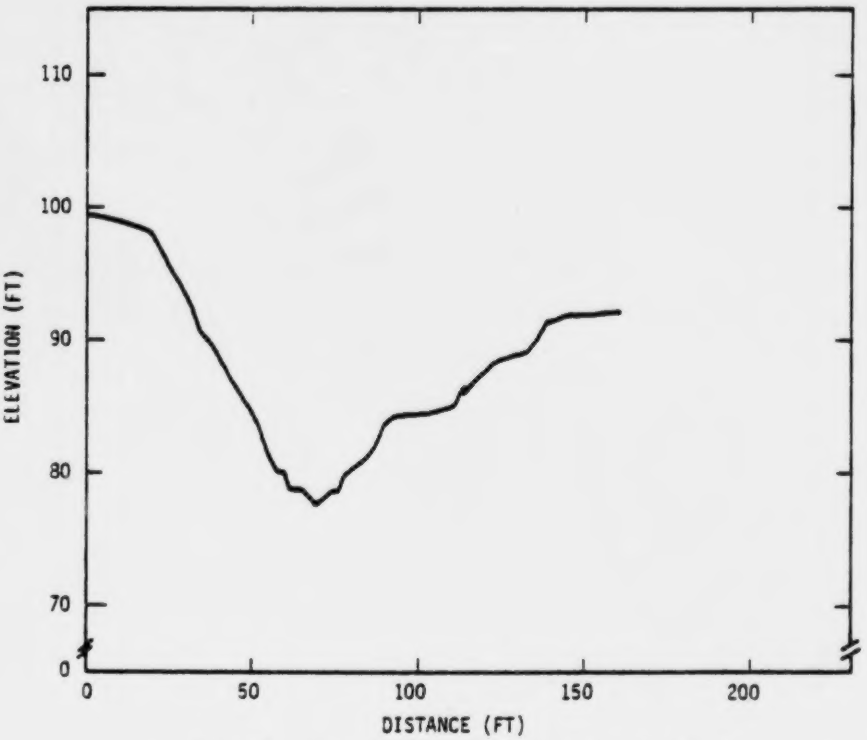
Channel cross-section at location 2, watershed 8B and 8D.



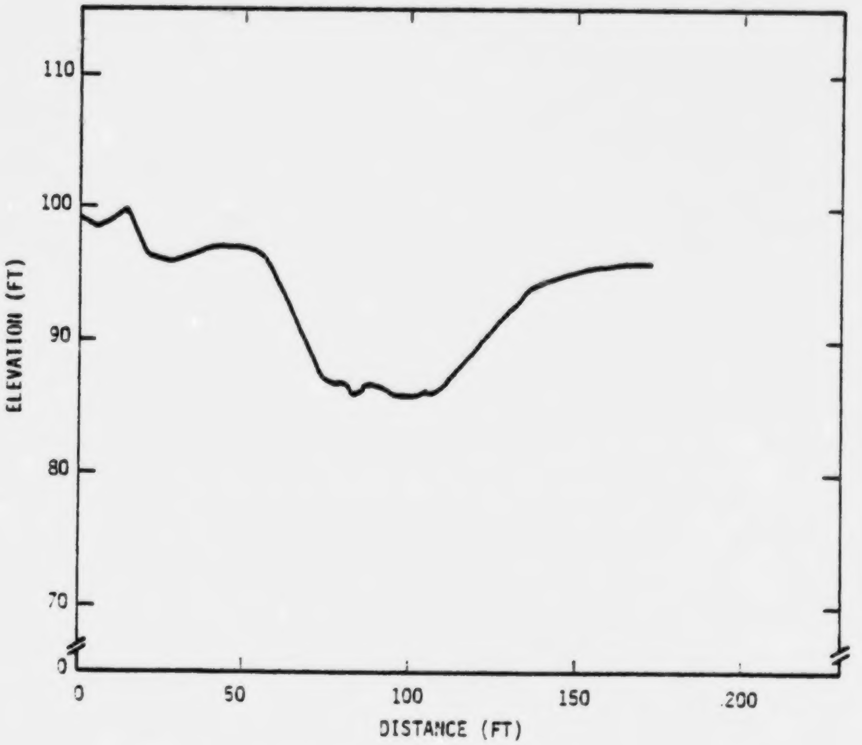
Channel cross-section at location 3, watersheds 3B and 3D.



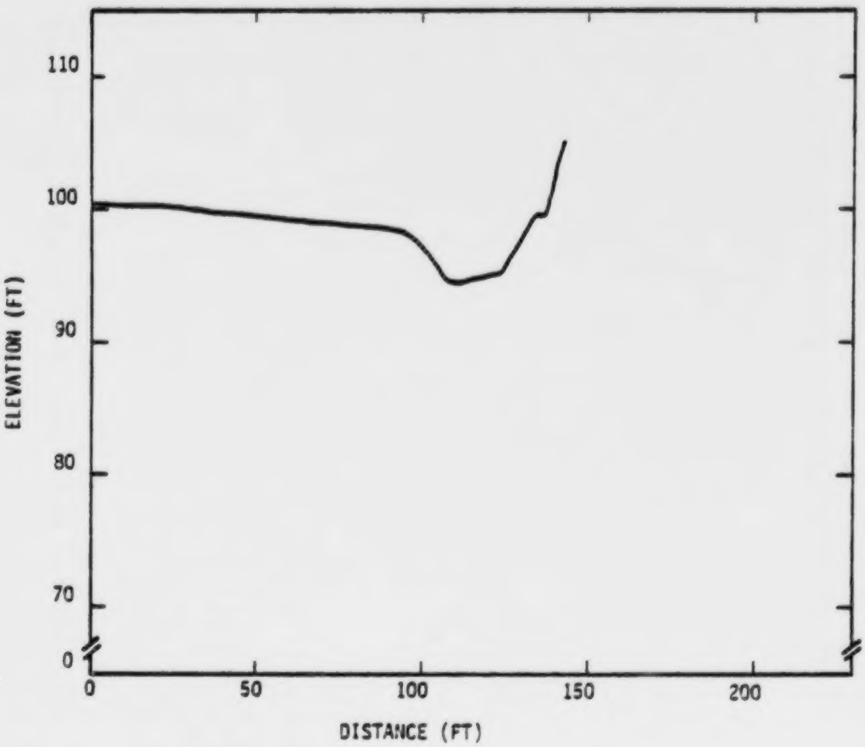
Channel cross-section at location 1, watershed 7.



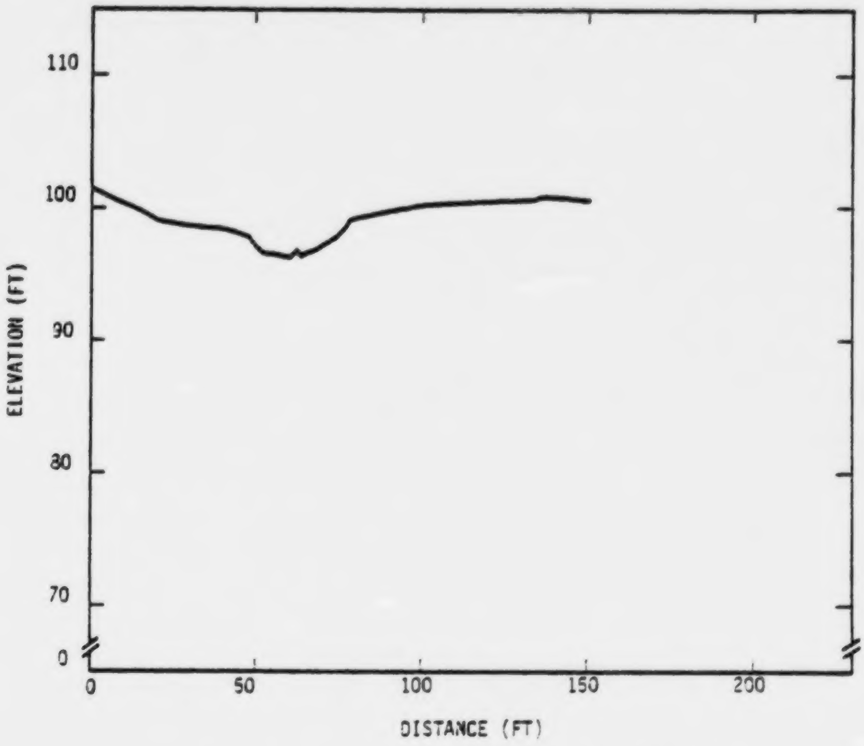
Channel cross-section at location 2, watershed 7.



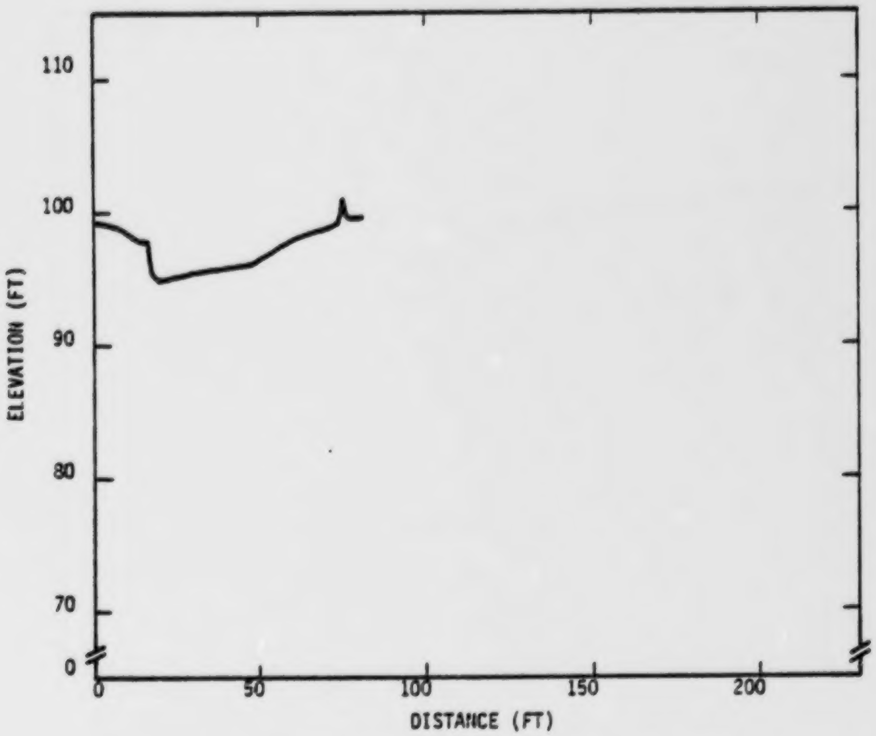
Channel cross-section at location 3, watershed 7.



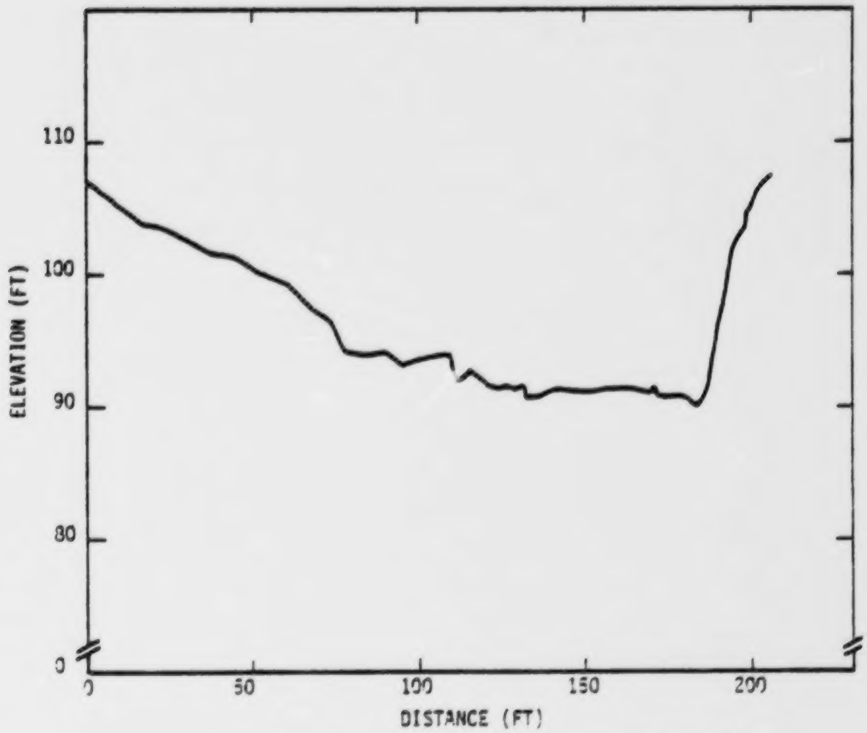
Channel cross-section at location 1 in the bowl.



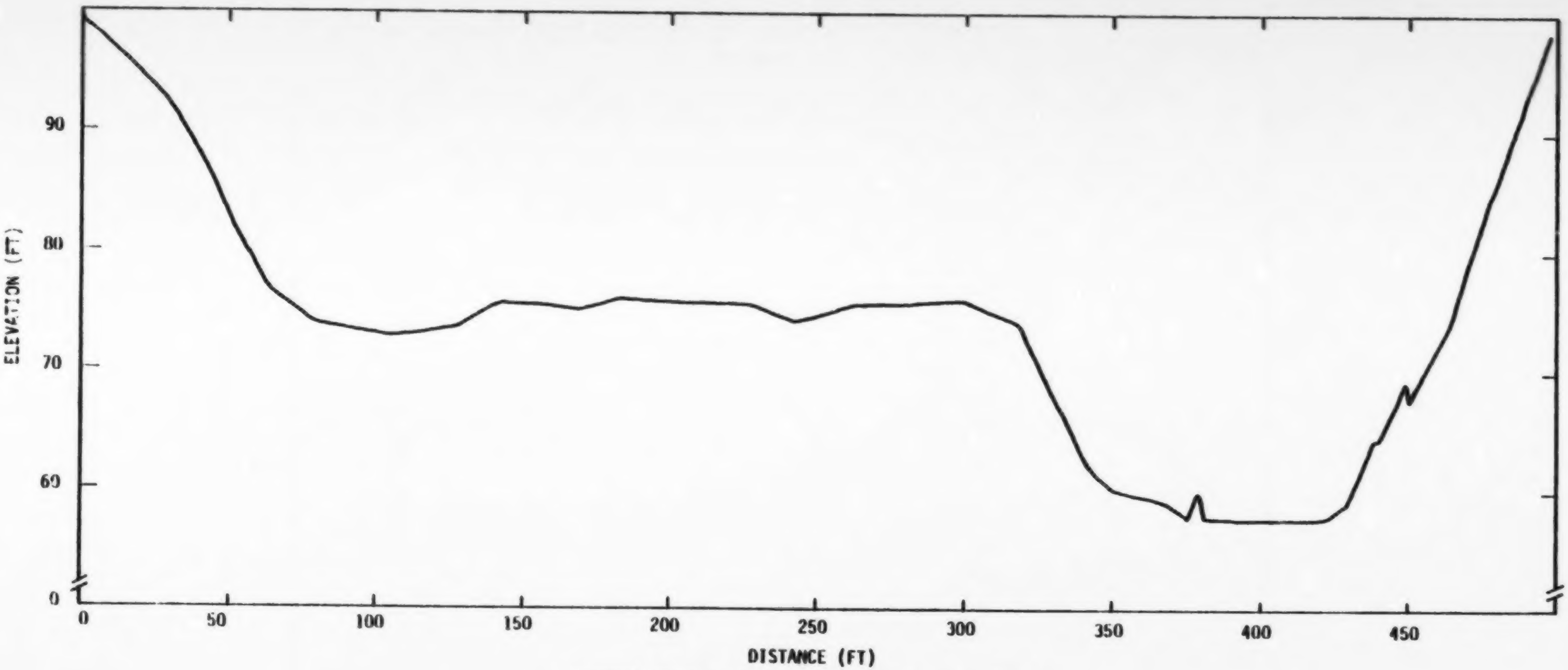
Channel cross-section at location 2 in the bowl.



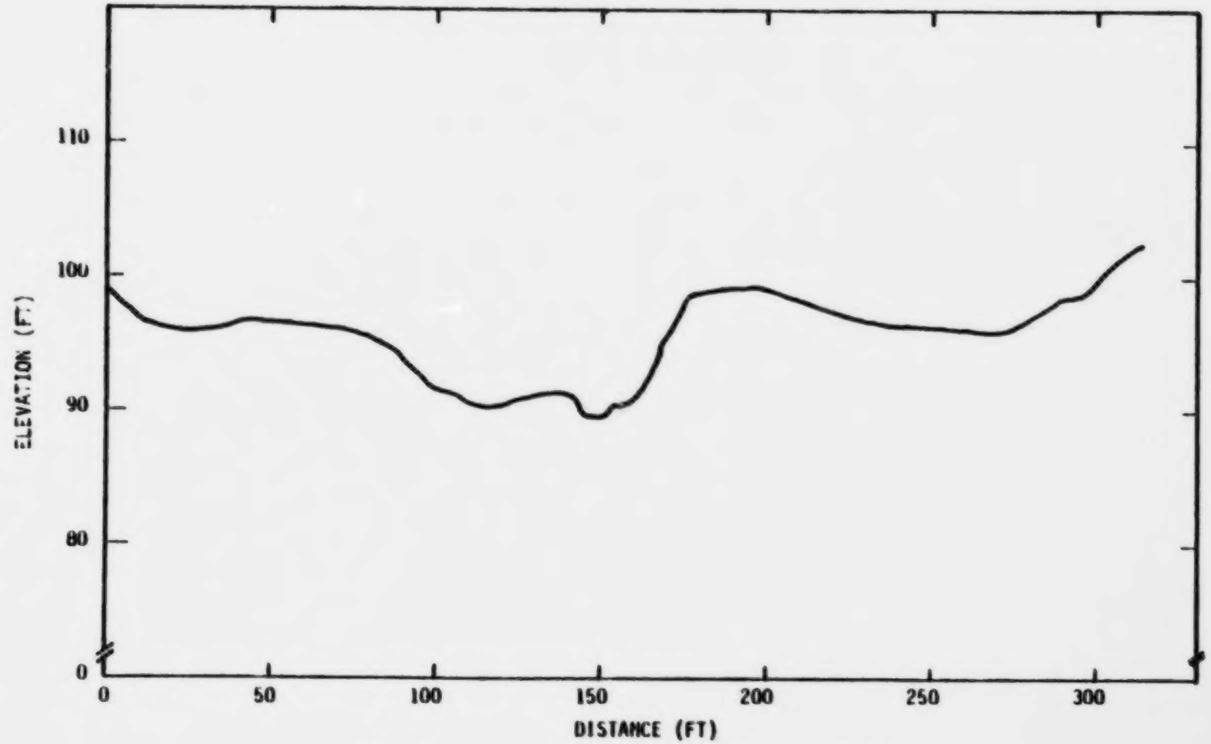
Channel cross-section at location 3 in the bowl.



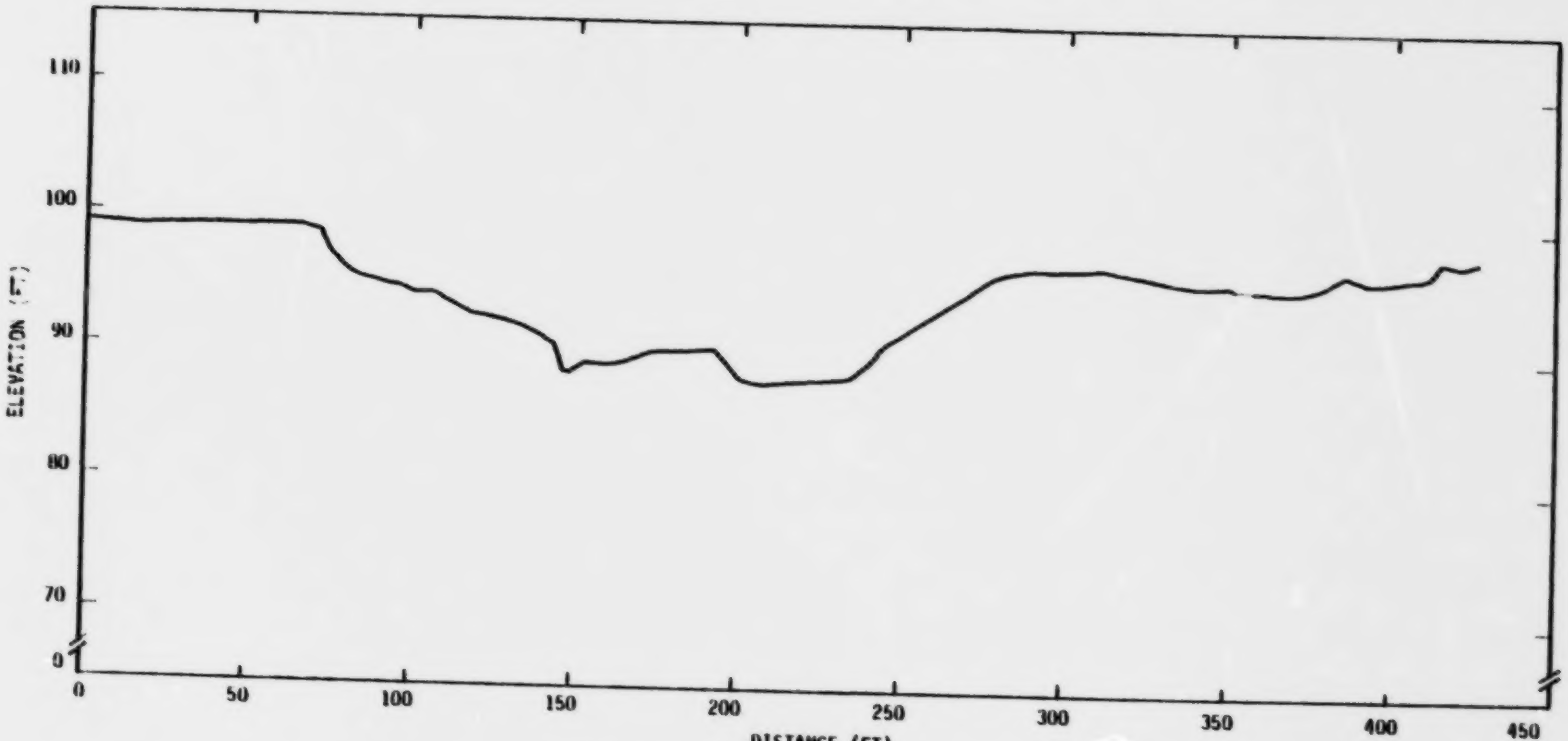
Channel cross-section at location 2, watershed 6.



Channel cross-section at location 1, watershed 6.



Channel cross-section at location 3, watershed 6.



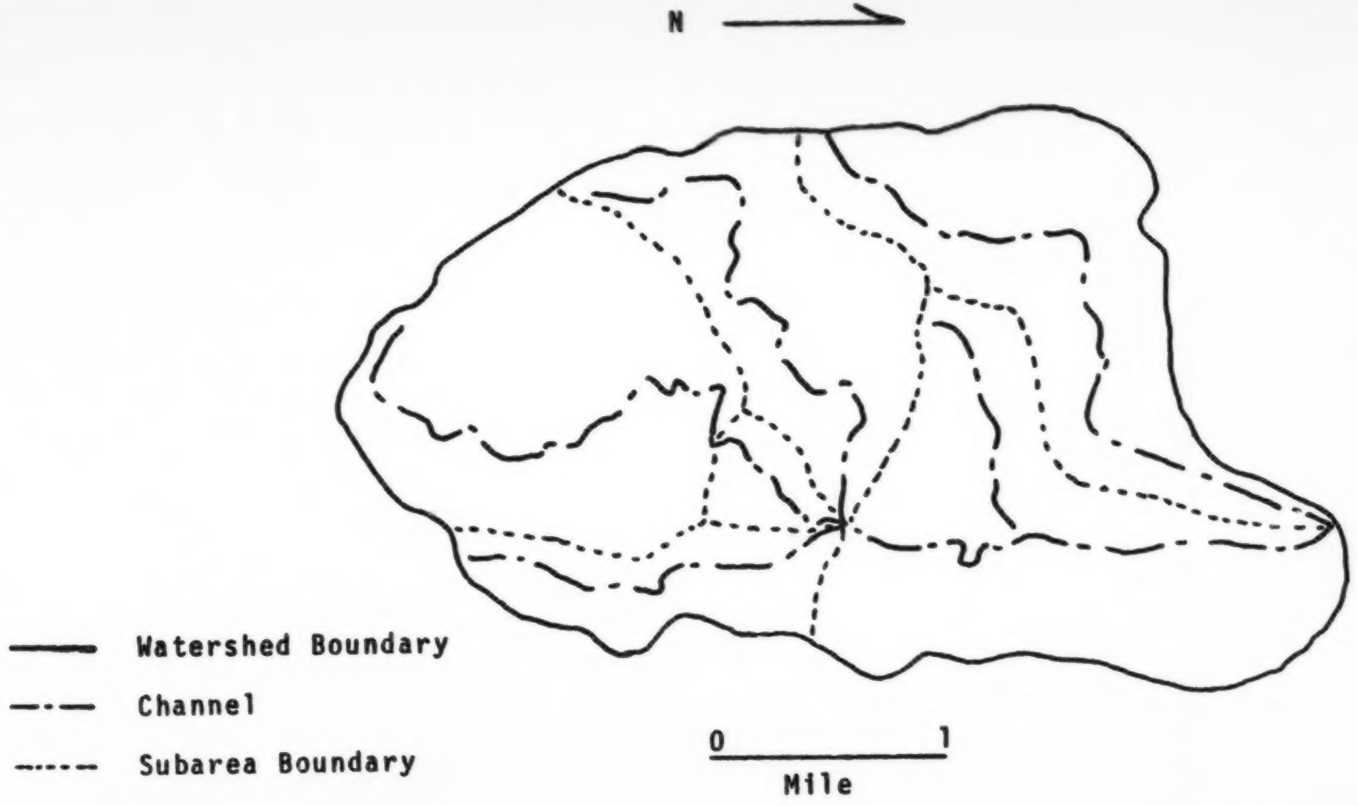
Channel cross-section at location 4, watershed 6.

# APPENDIX F-- COMPUTER PROGRAM FOR CALCULATING PEAK DISCHARGE BY SLOPE-AREA METHOD.

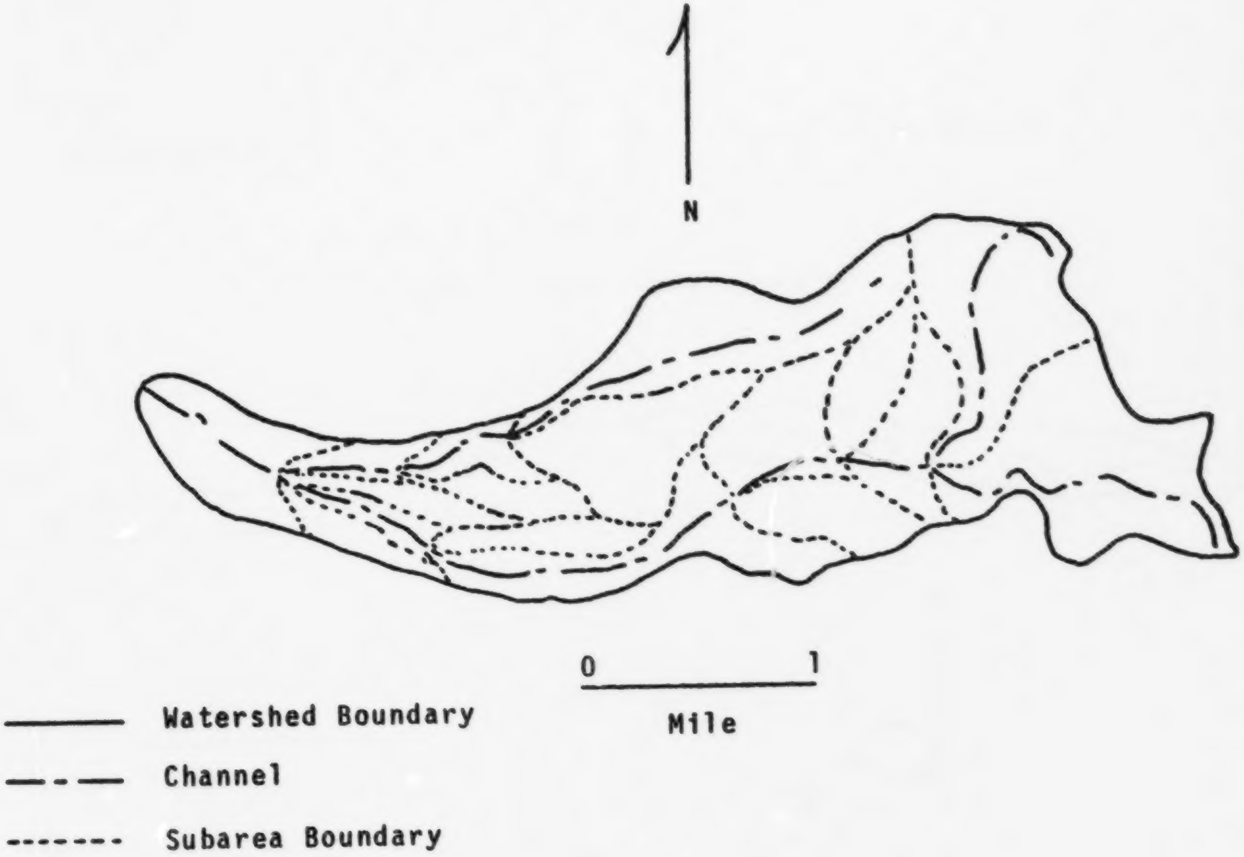
```
C   THIS PROGRAM DETERMINES AN ESTIMATE FOR FLOWRATE IN AN OPEN CHANNEL
C      BY MANNINGS EQUATION.  CROSS-SECTION AREA AND WETTED PERIMETER ARE
C      DETERMINED USING COORDINATES.
C
C
C   THREE GROUPS OF DATA ARE READ FOR EACH SITE.  THESE DATA AND THE
C      FORMAT FOR EACH ARE:
C
C   GROUP 1 (1 CARD ONLY)
C
C    CARD
C   COLUMNS  FIELD                           DATA
C
C    1-80      A80   SITE DESCRIPTION
C
C
C   GROUP 2 (1 CARD ONLY)
C
C    CARD
C   COLUMNS  FIELD                           DATA
C
C     1-5      I5    NUMBER OF POINTS AROUND THE FLOW CROSS-SECTION
C     6-10    5X     --- BLANK ---
C    11-15     F5.4  CHANNEL SLOPE OR ENERGY GRADIENT (FT/FT)
C    16-20    5X     --- BLANK ---
C    21-24     F4.3  CHANNEL ROUGHNESS COEFFICIENT (MANNINGS 'N')
C
C   GROUP 3 (MULTIPLE CARDS)
C
C    CARD
C   COLUMNS  FIELD                           DATA
C
C     1-5      F5.2  VERTICAL COORDINATE
C      6      1X     A ',' OR '/' MAY BE PLACED
C     7-10     F4.1  HORIZONTAL COORDINATE
C    11-13    3X     --- BLANK ---
C
C   (THIS SEQUENCE IS REPEATED GIVING THE COORDINATES OF 6 POINTS ON EACH
C      CARD)
C
C   (NOTE:  POINTS MUST BE GIVEN IN ORDER, EITHER CLOCKWISE OR COUNTER-
C      CLOCKWISE)
C
C
```

```
C
C   PROGRAM:
C
       CHARACTER INFO*80
       DIMENSION D(100),E(100)
C
C   READ ALL OF THE DATA FOR A SITE
C
     5 READ (5,1002,END=100) INFO
       READ (5,1000) N,S,RC
       READ (5,1001) (E(I),D(I),I=1,N)
C
C   SUM THE DIFFERENCES BETWEEN CROSS PRODUCTS AND DETERMINE AREA
C
       SUM = 0.
       DO 10 I=1,N
       J=I+1
       IF (J.GT.N) J=1
    10 SUM = SUM + D(I)*E(J)-E(I)*D(J)
       A = ABS(SUM)/2.
C
C   DETERMINE WETTED PERIMETER
C
       WP = 0.
       DO 20 I=2,N
       J=I-1
    20 WP = WP + SQRT((D(I)-D(J))**2+(E(I)-E(J))**2)
C
C   DETERMINE HYDRAULIC RADIUS, AVERAGE VELOCITY, AND FLOWRATE
C
       R = A/WP
       V = 1.49*R**(2./3.)*SQRT(S)/RC
       Q = A*V
C
C   OUTPUT RESULTS AND GO READ DATA FOR NEXT SITE
C
       WRITE (6,2002) INFO
       WRITE (6,2000) A,WP,R,S
       WRITE (6,2001) V,Q,N,RC
       GO TO 5
   100 STOP
  1000 FORMAT (I5,5X,F5.4,5X,F4.3)
  1001 FORMAT (6(F5.2,1X,F4.1,3X))
  1002 FORMAT (A80)
  2000 FORMAT (' ','A =',F8.3,5X,'WP =',F8.3,5X,'R =',F6.3,5X,'S =',F7.4)
  2001 FORMAT (' ','V =',F7.3,5X,'Q =',F10.2,5X,'N =',I2,5X,'RC =',F5.3/)
  2002 FORMAT (' ',A80)
       END
```

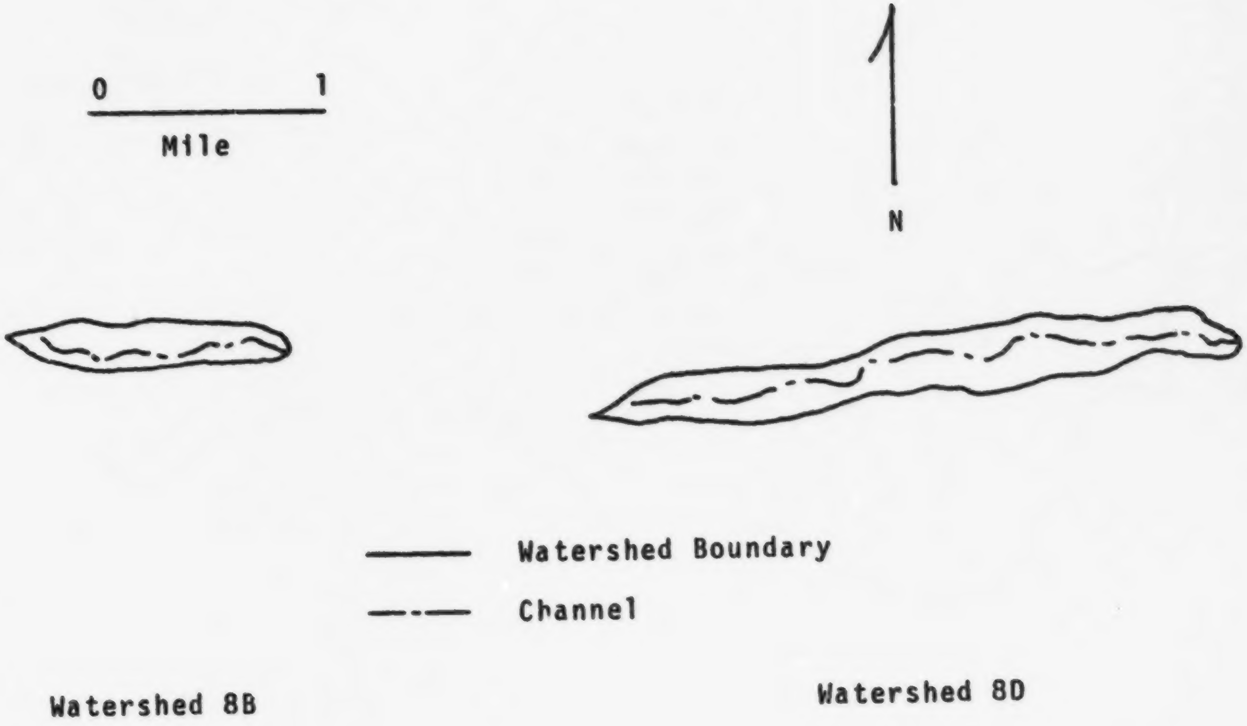
# APPENDIX G-- WATERSHED SUBAREA DELINEATIONS.

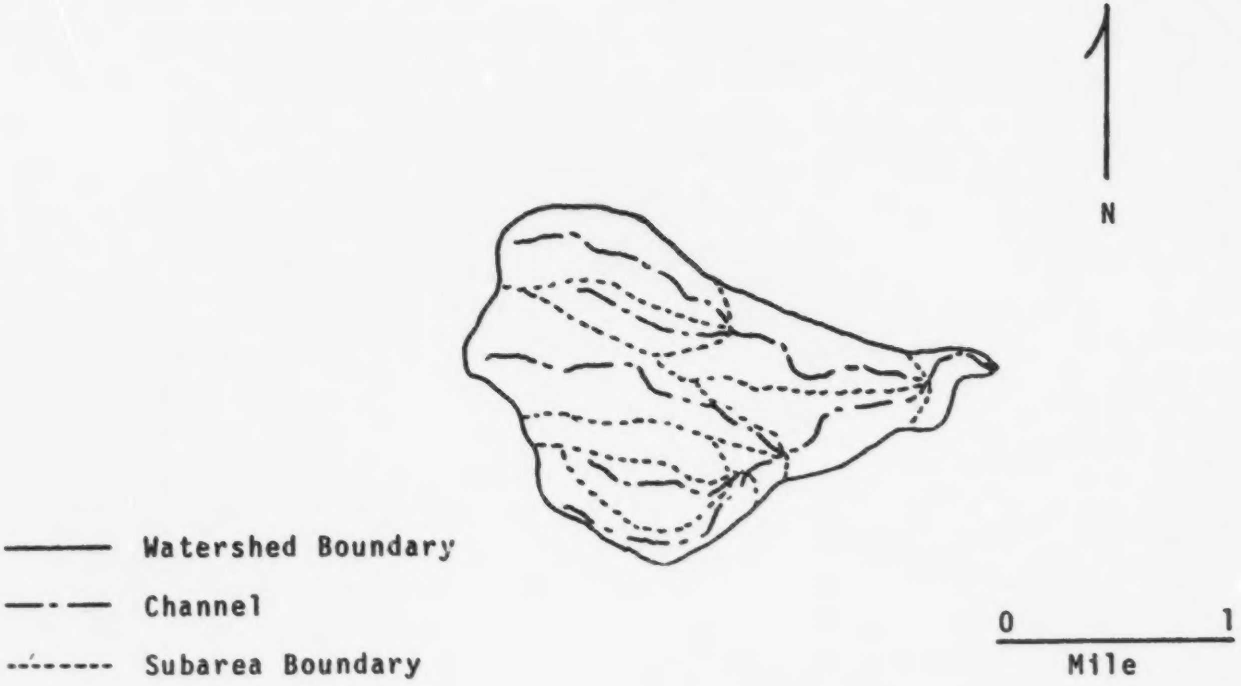


Watershed 1
Subarea Delineations

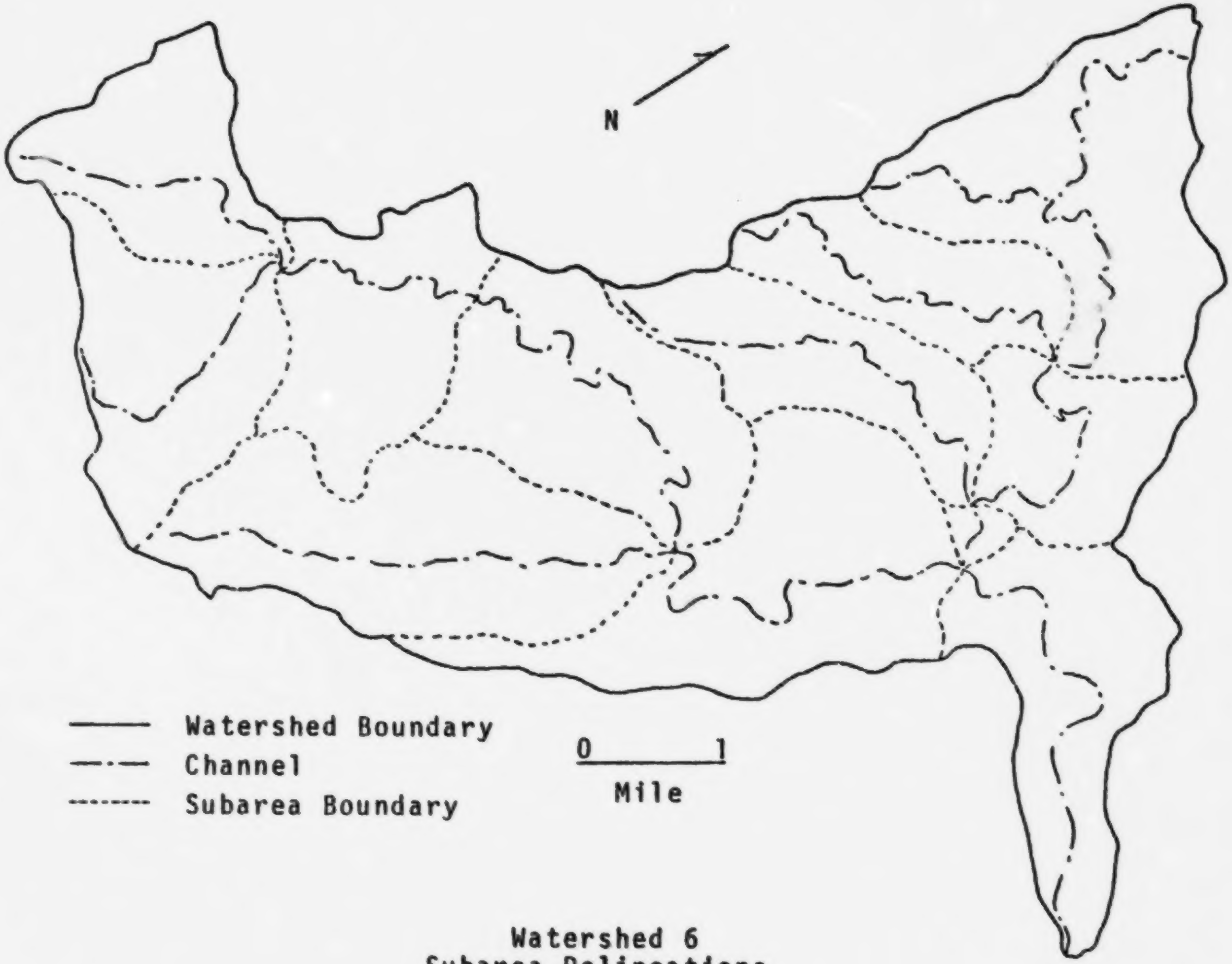


Watershed 10A6
Subarea Delineations


0
1
Mile
N
Watershed Boundary
Channel
Watershed 8B
Watershed 8D



Watershed 7
Subarea Delineations



Watershed 6
Subarea Delineations

# APPENDIX H--WATERSHED CHARACTERISTICS USED TO DETERMINE COMPOSITE RUNOFF CURVE NUMBERS.

## WATERSHED 1

| Percent Composition | Description |
|---|---|
| 27 | Dense trees along north facing slopes and streams, slopes > 50% (some 5-50%), sedimentary rock. |
| 5 | Sedimentary rock outcrop, very steep slope > 50%, mountain shrub vegetation, few trees. |
| 23 | Valley floor with dense mountain shrub vegetation, slopes 5-50%, dendritic drainage pattern. |
| 45 | Sedimentary rock with mountain shrub vegetation only along streams, slopes 5-50%, some > 50%. |

## WATERSHED 6

| Percent Composition | Description |
|---|---|
| 40 | Dense forest, slopes 5-50%, trees dense on north facing slopes, sparse on south facing. |
| 7 | Sedimentary, steep slope > 50%, sparsely vegetated with trees along drainages and on north facing slopes. |
| 2 | Stream bottom, mountain shrub vegetation dense along stream bank, slopes < 5%, bare stream bottom. |
| 1 | Highly downcut sedimentary hills, 5-50%, desert shrub vegetation only along streams. |
| 24 | Steep sedimentary mountain shrub community, slopes > 50%, dense vegetation, some rock outcrops, parallel V-shaped drainages. |

## WATERSHED 6 (Continued)

| Percent Composition | Description |
|---|---|
| 2 | Very steep topography, vertical walls, very sparse mountain shrub vegetation. |
| 14 | Steep V-shaped valley with rock outcrop at upper reaches, slopes > 50%, dense mountain shrub vegetation. |
| 10 | Dense trees along north facing slopes and streams, slopes > 50% (some 5-50%), sedimentary rock. |

## WATERSHED 7

| Percent Composition | Description |
|---|---|
| 43 | Fluvial plain with parallel drainage pattern, moderately dense mountain shrub vegetation. |
| 1 | Stream bottom, mountain shrub vegetation dense along bank, slope < 5%, stream bottom bare. |
| 56 | Steep sedimentary, mountain shrub community, slope > 50%, dense vegetation, some rock outcrops, parallel V-shaped drainage pattern. |

## WATERSHED 8B

| Percent Composition | Description |
|---|---|
| 79 | Mountain shrub community, slope < 5%, moderate vegetation, dendritic drainage pattern. |
| 21 | River bottom with dense mountain shrub vegetation, slope < 5%, dendritic drainage pattern. |

## WATERSHED 8D

| Percent Composition | Description |
|---|---|
| 78 | Mountain shrub community, slope < 5%, moderate vegetation, dendritic drainage pattern. |
| 22 | Flat downcut plain, slope < 5%, mountain shrub vegetation along stream channels. |

## WATERSHED 10A6

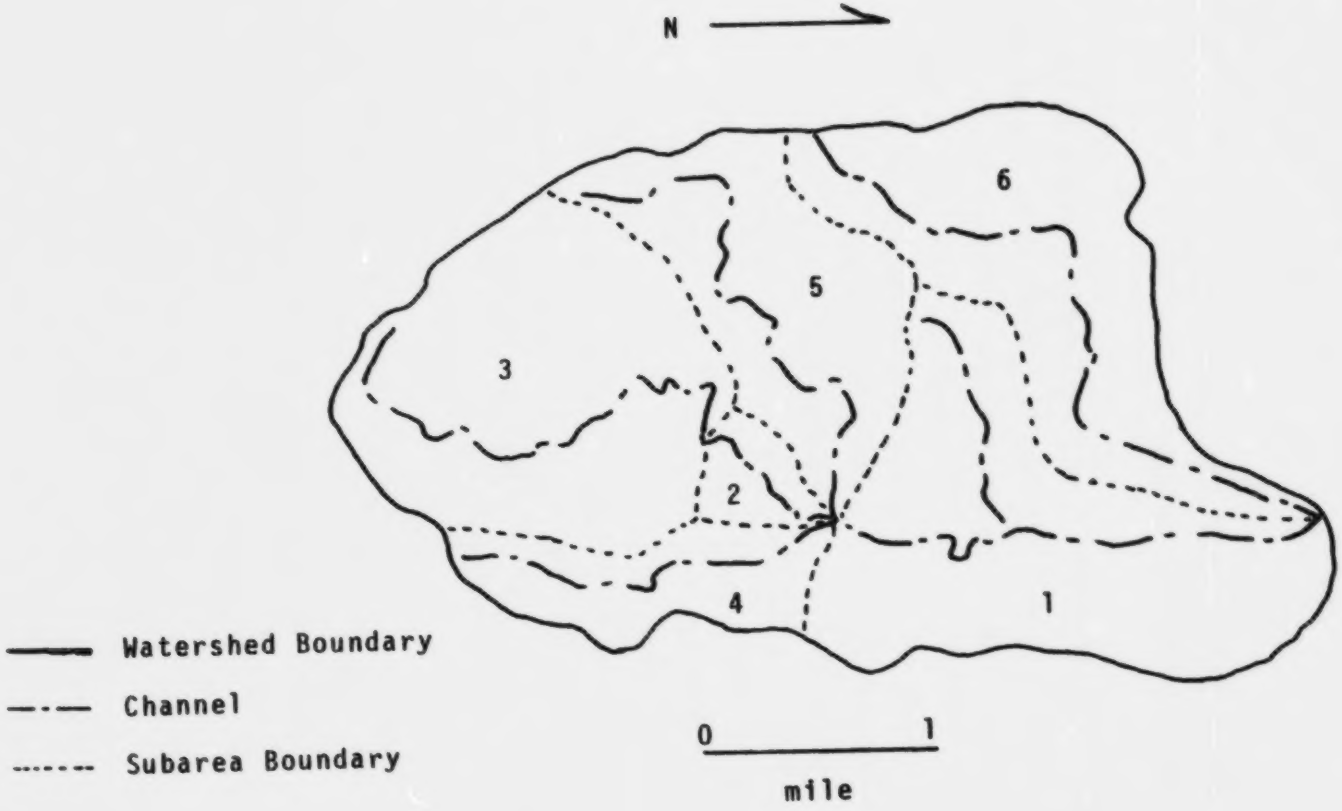
| Percent Composition | Description |
|---|---|
| 4 | Desert shrub community, flat, slopes < 5%, mottled soil (appearance). |

WATERSHED 10A6 (Continued)

| Percent Composition | Description |
|---|---|
| 24 | Fluvial plain, slope 5-50%, desert shrub vegetation with denser riparian vegetation. |
| 3 | Exposed, tilted, resistant, interbedded outcrop on fluvial plain, slopes 5-50%, desert shrub vegetation. |
| 57 | Mountain shrub community, slopes > 50% (some 5-50%), sedimentary rock material, denser riparian vegetation. |
| 10 | Dense mountain shrub vegetation, slope 5-50%, sedimentary rock. |
| 2 | Sedimentary, slopes 5-50%, desert shrub vegetation. |

# APPENDIX I--DEVELOPMENT OF UNIT HYDROGRAPH--WATERSHED 1 SOIL CONSERVATION METHOD.

Subareas within Watershed 1 were delineated as shown in the accompanying illustration. The time of concentration of each subarea and the travel time to the mouth of the watershed were calculated using Kirpich's formula. The resulting times were rounded to the nearest value for which unit discharges were given in the tabular discharge tables (Soil Conservation Service, 1978). The discharge values for the various subareas and their corresponding time of concentration and travel time are shown in the accompanying table. Since the discharges were given in units of cubic feet per second per square mile per inch of runoff, the coordinates of the unit hydrograph were obtained by multiplying these discharge values by the size of each subarea and then summing all such products for that particular hydrograph time. The hydrograph times reported herein assume that precipitation occurs during the middle of the 24-hour duration inherent within the methods.



Watershed 1
Subarea Delineations

## DEVELOPMENT OF UNIT HYDROGRAPH -- WATERSHED 1

| | Subareas | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Hydrograph Time (hours) | $T_t$ = 0 hr<br>$T_c$ = 0.75 hr<br>1.79 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.30 hr<br>0.22 sq mi | $T_t$ = 1.00 hr<br>$T_c$ = 0.50 hr<br>1.81 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.30 hr<br>0.58 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.50 hr<br>1.11 sq mi | $T_t$ = 0 hr<br>$T_c$ = 0.75 hr<br>1.72 sq mi | CFS/ Inch Runoff |
| 0.0 | 15 | 10 | 7 | 10 | 9 | 15 | 83 |
| 0.5 | 29 | 17 | 11 | 17 | 15 | 29 | 152 |
| 0.6 | 36 | 19 | 13 | 19 | 16 | 36 | 183 |
| 0.7 | 56 | 21 | 14 | 21 | 18 | 56 | 259 |
| 0.8 | 98 | 24 | 16 | 24 | 20 | 98 | 414 |
| 0.9 | 163 | 27 | 17 | 27 | 23 | 163 | 650 |
| 1.0 | 249 | 32 | 19 | 32 | 26 | 249 | 963 |
| 1.1 | 329 | 41 | 22 | 41 | 32 | 329 | 1,263 |
| 1.2 | 377 | 63 | 25 | 63 | 43 | 377 | 1,467 |
| 1.3 | 389 | 114 | 31 | 114 | 67 | 389 | 1,587 |
| 1.4 | 369 | 203 | 41 | 203 | 114 | 369 | 1,658 |
| 1.5 | 325 | 316 | 63 | 316 | 186 | 325 | 1,714 |
| 1.6 | 275 | 413 | 102 | 413 | 271 | 275 | 1,781 |
| 1.7 | 231 | 457 | 162 | 457 | 346 | 231 | 1,854 |
| 1.8 | 194 | 443 | 235 | 443 | 391 | 194 | 1,895 |
| 1.9 | 165 | 389 | 305 | 389 | 398 | 165 | 1,884 |

## DEVELOPMENT OF UNIT HYDROGRAPH -- WATERSHED 1 - CONTINUED

| Hydrograph Time (hours) | Subareas | | | | | | CFS/ Inch Runoff |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| | $T_t$ = 0 hr<br>$T_c$ = 0.75 hr<br>1.79 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.30 hr<br>0.22 sq mi | $T_t$ = 1.00 hr<br>$T_c$ = 0.50 hr<br>1.81 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.30 hr<br>0.58 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.50 hr<br>1.11 sq mi | $T_t$ = 0 hr<br>$T_c$ = 0.75 hr<br>1.72 sq mi | |
| 2.0 | 142 | 319 | 357 | 319 | 372 | 142 | 1,813 |
| 2.1 | 123 | 252 | 379 | 252 | 328 | 123 | 1,683 |
| 2.2 | 107 | 198 | 371 | 198 | 277 | 107 | 1,513 |
| 2.4 | 84 | 127 | 298 | 127 | 189 | 84 | 1,146 |
| 2.6 | 69 | 90 | 211 | 90 | 130 | 69 | 840 |
| 2.8 | 58 | 71 | 146 | 71 | 95 | 58 | 630 |
| 3.0 | 51 | 60 | 104 | 60 | 74 | 51 | 497 |
| 3.2 | 45 | 53 | 80 | 53 | 61 | 45 | 413 |
| 3.4 | 41 | 47 | 65 | 47 | 53 | 41 | 358 |
| 3.6 | 38 | 43 | 55 | 43 | 47 | 38 | 320 |
| 3.8 | 35 | 40 | 49 | 40 | 43 | 35 | 291 |
| 4.0 | 33 | 37 | 44 | 37 | 39 | 33 | 268 |
| 4.2 | 31 | 35 | 40 | 35 | 37 | 31 | 250 |
| 4.4 | 30 | 33 | 37 | 33 | 34 | 30 | 236 |
| 4.6 | 28 | 31 | 35 | 31 | 32 | 28 | 222 |
| 4.8 | 27 | 29 | 33 | 29 | 31 | 27 | 212 |

## DEVELOPMENT OF UNIT HYDROGRAPH -- WATERSHED 1 - CONTINUED

| Hydrograph Time (hours) | Subareas | | | | | | CFS/ Inch Runoff |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| | $T_t$ = 0 hr<br>$T_c$ = 0.75 hr<br>1.79 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.30 hr<br>0.22 sq mi | $T_t$ = 1.00 hr<br>$T_c$ = 0.50 hr<br>1.81 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.30 hr<br>0.58 sq mi | $T_t$ = 0.75 hr<br>$T_c$ = 0.50 hr<br>1.11 sq mi | $T_t$ = 0 hr<br>$T_c$ = 0.75 hr<br>1.72 sq mi | |
| 5.0 | 26 | 28 | 31 | 28 | 29 | 26 | 202 |
| 5.5 | 23 | 25 | 27 | 25 | 26 | 23 | 178 |
| 6.0 | 22 | 23 | 25 | 23 | 24 | 22 | 168 |
| 6.5 | 20 | 21 | 23 | 21 | 22 | 20 | 153 |
| 7.0 | 19 | 20 | 21 | 20 | 20 | 19 | 143 |
| 7.5 | 17 | 18 | 19 | 18 | 19 | 17 | 130 |
| 8.0 | 17 | 17 | 18 | 17 | 18 | 17 | 126 |
| 8.5 | 16 | 16 | 17 | 16 | 17 | 16 | 119 |
| 9.0 | 15 | 15 | 16 | 15 | 16 | 15 | 111 |
| 10.0 | 14 | 14 | 15 | 14 | 14 | 14 | 103 |
| 11.0 | 13 | 13 | 13 | 13 | 17 | 13 | 94 |
| 12.0 | 12 | 12 | 12 | 12 | 12 | 12 | 87 |
| 13.0 | 11 | 11 | 12 | 11 | 11 | 11 | 81 |
| 14.0 | 3 | 8 | 10 | 8 | 8 | 3 | 44 |
| 15.0 | 2 | 1 | 5 | 1 | 5 | 2 | 22 |
| 16.0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| 17.0 | | | 0 | | | | 0 |

# APPENDIX J-- COMPUTER PROGRAM FOR COMPUTING GROUND ELEVATIONS ALONG EROSION TRANSECTS---GROUND ELEVATIONS ALONG EROSION TRANSECTS---COMPUTER PROGRAM FOR COMPUTING DIFFERENCES IN GROUND ELEVATIONS ALONG EROSION TRANSECTS.

```
C   THIS PROGRAM PROCESSES EROSION TRANSECT OBSERVATIONS AND OUTPUTS
C      GROUND FLEVATIONS FOR EACH TRANSECT STATION
C
C   SEPARATE SITES ARE DISTINGUISHED ON THE BASIS OF WATERSHED AND
C      LOCATION.  SEPARATE TRANSECTS AT A SITE ARE DISTINGUISHED BY DATE
C
C   DATA FOR A TRANSECT MUST CONSIST OF A HEADER CARD (SEE NOTE) FOLLOWED
C      BY THE TRANSECT OBSERVATIONS.  THE DATA CARD FORMAT IS:
C
C    CARD
C   COLUMNS  FIELD                          VARIABLE
C
C     1-4     A4     WATERSHED (10A6, WS-1, WS-6, WS-7, 8BBD, OR BOWL)
C    5-10    3I2     DATE (MONTH, DAY, YEAR)
C   11-12     A2     DATA TYPE (ALWAYS 'ER' FOR EROSION TRANSECT)
C   13-14     I2     LOCATION (1, 2, ETC.)
C   15-19     5X     --- BLANK ---
C   20-21     I2     STATION (1, 2, ETC.)
C   22-24     3X     --- BLANK ---
C    25       A1     FLAG FOR AN UNOBSERVED STATION ('B' IF UNOBSERVED,
C                       OTHERWISE BLANK)
C   26-30    F5.1    VERTICAL DISTANCE
C   31-80     A50    REMARKS
C
C    (NOTE:  THE HEADER CARD SUPPLIES DATA FOR THE SLOPE OF THE CABLE.
C       THE 'STATION' RECORDED IS THE END STATION OF THE TRANSECT AND THE
C        'VERTICAL DISTANCE' IS THE CABLE RISE/FALL AT THE END STATION
C        FROM STATION 1)
C
C
C
      CHARACTER WS*4(2),B(12),RMKS*50,F
      DIMENSION IDATE(3),JDATE(3,12),LO(2),X(35),Y(35,12),E(35,12)
      DIMENSION STA(35)
      J1=0
C
C   READ THE FIRST CARD
C
    5 READ (5,1001) WS(1),(IDATE(I),I=1,3),LO(1),IH,V
C
C   STORE WATERSHED AND LOCATION, AND INITIALIZE TRANSECT NUMBER
C
   10 WS(2) = WS(1)
      LO(2) = LO(1)
      M=1
      N=IH
C
C   STORE TRANSECT DATE AND COMPUTE CABLE SLOPE
```

```
C
   25 DO 28 I=1,3
   28 JDATE(I,M)=IDATE(I)
      S=V/((IH-1.)*15.24)
C
C  READ TRANSECT DATA AND COMPUTE ELEVATIONS
C
      DO 30 I=1,IH
      READ (5,1002) STA(I),F,Y(I,M)
      X(I)=(STA(I)-1.)*15.24
      IF (F.EQ.'B') THEN DO
          F(I,M)=10000.
        ELSE DO
          F(I,M)=(100.+S*X(I))-Y(I,M)
        END IF
   30 CONTINUE
C
C  READ HEADER CARD FOR NEXT DATA
C
   31 READ (5,1001,END=38) WS(1),(IDATE(I),I=1,3),LO(1),IH,V
C
C  IF DATA ARE FOR A NEW SITE (DIFFERENT WATERSHED OR LOCATION) GO WRITE
C     OUTPUT FOR THE LAST SITE
C
      IF (WS(1).NE.WS(2)) GO TO 40
      IF (LO(1).NE.LO(2)) GO TO 40
C
C  IF DATA ARE FOR THE SAME SITE (DIFFERENT DATE) INCREMENT TRANSECT
C     NUMBER AND GO PROCESS THE DATA
C
      DO 32 I=1,3
      IF (IDATE(I).NE.JDATE(I,M)) THEN DO
          M=M+1
          GO TO 25
        END IF
   32 CONTINUE
   38 J1=1
C
C  WRITE THE OUTPUT FOR A SITE (WATERSHED AND LOCATION).  THEN GO
C     PROCESS THE DATA FOR THE NEXT SITE
C
   40 WRITE (6,2001) WS(2), LO(2)
      DO 42 J=1,M
   42 B(J) = ' '
      WRITE (6,2002) ((JDATE(I,J),I=1,3),J=1,M)
      WRITE (6,2003) (B(J),J=1,M)
      WRITE (6,2004)
      DO 50 I=1,N
   50 WRITE (6,2005) STA(I),(E(I,J),J=1,M)
      IF (J1.EQ.1) STOP
      GO TO 10
 1001 FORMAT (A4,3I2,2X,I2,5X,I2,4X,F5.1)
 1002 FORMAT (19X,F2.0,3X,A1,F5.1)
 2001 FORMAT ('1'//////////' ','WATERSHED:',2X,A4,10X,'LOCATION:',I4//)
 2002 FORMAT (' ',9X,12(I2,'/',I2,'/',I2,2X))
 2003 FORMAT (' ','STATION',1X,12(A1,2X,'ELEV',3X))
 2004 FORMAT (' ')
 2005 FORMAT (' ',1X,F4.1,1X,12(4X,F6.2))
      END
```

| SITE: | 10A6-1 | 10A6-2 | 10A6-3 | 10A6-4 | WS-1-1 | WS-1-2 | WS-1-3 |
|---|---|---|---|---|---|---|---|
| DATE: | 5/17/79 | 5/17/79 | 5/17/79 | 5/17/79 | 5/20/79 | 5/20/79 | 5/20/79 |
| STATION | ELEV | ELEV | ELEV | ELEV | ELEV | ELEV | ELEV |
| 1.0 | 97.20 | 95.20 | 93.30 | 91.10 | 86.40 | 95.60 | 86.70 |
| 2.0 | 94.90 | 94.00 | 96.20 | 90.50 | 89.20 | 86.70 | 87.00 |
| 3.0 | 94.30 | 94.30 | 90.50 | 89.50 | 84.40 | 82.90 | 85.40 |
| 4.0 | 94.30 | 91.40 | 86.00 | 86.00 | 84.10 | 75.20 | 86.00 |
| 5.0 | 94.00 | 89.80 | 82.90 | 84.40 | 83.50 | 73.00 | 86.70 |
| 6.0 | 92.70 | 87.60 | 78.40 | 84.40 | 82.50 | 70.80 | 85.40 |
| 7.0 | 92.70 | 86.40 | 75.90 | 84.80 | 82.50 | 64.80 | 86.00 |
| 8.0 | 92.70 | 84.10 | 70.80 | 86.70 | 79.70 | 62.20 | 84.80 |
| 9.0 | 91.80 | 84.80 | 68.90 | 90.20 | 80.00 | 60.00 | 85.40 |
| 10.0 | 91.80 | 86.40 | 69.50 | 84.80 | 79.00 | 60.30 | 85.10 |
| 11.0 | 91.40 | 87.90 | 71.10 | 84.80 | 79.70 | 60.00 | 90.20 |
| 12.0 | 91.80 | 90.80 | 73.30 | 82.20 | 80.00 | 59.40 | 88.60 |
| 13.0 | 91.80 | 93.00 | 74.30 | 79.40 | 79.40 | 60.30 | 89.80 |
| 14.0 | 91.80 | UULUUU | 76.20 | 81.00 | 79.70 | 63.20 | 88.60 |
| 15.0 | 93.00 | UULUUU | 75.90 | 77.10 | 78.40 | 65.10 | 90.20 |
| 16.0 | 93.00 | UULUUU | 75.80 | 77.10 | 75.90 | 67.00 | 88.90 |
| 17.0 | 94.30 | UULUUU | 76.50 | 78.40 | 75.90 | 68.60 | 88.60 |
| 18.0 | 94.30 | UULUUU | 78.10 | 78.70 | 75.90 | 68.90 | 87.90 |
| 19.0 | 94.30 | UULUUU | 79.70 | 79.40 | 78.40 | 69.50 | 90.20 |
| 20.0 | 94.30 | UULUUU | 82.20 | 79.70 | 77.80 | 67.60 | 90.20 |
| 21.0 | 95.60 | UULUUU | 84.80 | 80.00 | 78.40 | 68.60 | 88.60 |
| 22.0 | 94.30 | UULUUU | 85.70 | 79.70 | 77.50 | 68.60 | 88.30 |
| 23.0 | 94.30 | UULUUU | 88.30 | 78.40 | 77.50 | 70.50 | 87.90 |
| 24.0 | 92.70 | UULUUU | 84.40 | 80.30 | 80.60 | 72.70 | 88.60 |
| 25.0 | 93.60 | UULUUU | 83.80 | 80.00 | 86.40 | 71.40 | 88.60 |
| 26.0 | 93.60 | UULUUU | 85.40 | 79.70 | 87.00 | 70.20 | 88.90 |
| 27.0 | 95.20 | UULUUU | 88.30 | 80.00 | 90.20 | 73.00 | 89.50 |
| 28.0 | 93.60 | UULUUU | 89.20 | 81.00 | 90.80 | 72.70 | 96.20 |
| 29.0 | 93.60 | UULUUU | 91.10 | 82.20 | 91.40 | 75.20 | 87.90 |
| 30.0 | 94.30 | UULUUU | 91.80 | 82.20 | 91.10 | 78.40 | 88.60 |
| 31.0 | 94.00 | UULUUU | 93.00 | 83.50 | 91.70 | 82.20 | 88.60 |
| 32.0 | 94.90 | UULUUU | 94.60 | 87.30 | 93.00 | 88.40 | 88.60 |
| 33.0 | 95.90 | UULUUU | 94.30 | 89.80 | 93.30 | 88.90 | 90.50 |
| 34.0 | 95.20 | UULUUU | 93.60 | 91.40 | 96.20 | 90.20 | 86.70 |

| SITE: | WS-1-4 | WS-6-1 | WS-6-2 | WS-6-3 | WS-6-4 | WS-6-5 | WS-7-1 |
|---|---|---|---|---|---|---|---|
| DATE: | 5/20/79 | 5/18/79 | 5/18/79 | 5/18/79 | 6/ 7/79 | 6/ 7/79 | 6/10/79 |
| STATION | ELEV | ELEV | ELEV | ELEV | ELEV | ELEV | ELEV |
| 1.0 | 92.70 | 97.20 | 81.30 | 97.20 | 99.40 | 89.80 | ****** |
| 2.0 | 87.30 | 96.80 | 80.00 | 96.80 | 93.00 | 88.68 | 72.70 |
| 3.0 | 81.00 | 94.30 | 80.30 | 96.20 | 91.10 | 83.67 | 72.10 |
| 4.0 | 74.30 | 93.00 | 80.00 | 94.30 | 88.60 | 82.75 | 72.40 |
| 5.0 | 69.50 | 92.40 | 82.20 | 93.30 | 90.50 | 81.54 | 77.10 |
| 6.0 | 66.70 | 91.80 | 83.50 | 94.00 | 88.60 | 78.42 | 78.70 |
| 7.0 | 65.10 | 91.40 | 84.80 | 92.40 | 85.40 | 75.91 | 77.80 |
| 8.0 | 67.00 | 91.10 | 85.10 | 94.90 | 83.50 | 73.49 | 72.70 |
| 9.0 | 67.90 | 89.80 | 84.10 | 94.90 | 81.00 | 72.28 | 74.00 |
| 10.0 | 68.20 | 87.90 | 81.30 | 94.90 | 79.70 | 71.66 | 73.60 |
| 11.0 | 67.90 | 84.10 | 76.20 | 93.60 | 78.40 | 71.15 | 74.30 |
| 12.0 | 68.90 | 80.60 | 73.30 | 90.80 | 77.50 | 70.63 | 72.40 |
| 13.0 | 67.30 | 83.50 | 71.80 | 88.30 | 77.50 | 72.82 | 71.80 |
| 14.0 | 62.90 | 88.60 | 70.80 | 87.60 | 77.50 | 69.10 | 71.80 |
| 15.0 | 60.00 | 86.70 | 70.80 | 87.30 | 77.10 | 69.79 | 74.60 |
| 16.0 | 56.80 | 86.70 | 71.10 | 85.40 | 76.50 | 69.57 | 77.50 |
| 17.0 | 54.30 | 86.70 | 69.80 | 85.40 | 75.90 | 70.56 | 78.70 |
| 18.0 | 55.90 | 87.60 | 69.80 | 85.40 | 75.90 | 69.44 | 80.60 |
| 19.0 | 58.40 | 89.20 | 70.50 | 86.40 | 74.00 | 69.13 | 81.00 |
| 20.0 | 60.60 | 89.80 | 70.50 | 87.90 | 73.60 | 69.81 | 82.50 |
| 21.0 | 61.30 | 89.80 | 71.40 | 88.60 | 72.10 | 71.20 | 82.90 |
| 22.0 | 61.00 | 89.80 | 71.10 | 88.60 | 71.40 | 72.18 | 81.30 |
| 23.0 | 64.80 | 91.40 | 70.50 | 88.60 | 73.00 | 74.87 | 81.00 |
| 24.0 | 65.10 | 89.80 | 70.50 | 87.60 | 74.00 | 76.15 | 80.30 |
| 25.0 | 65.40 | 89.80 | 70.20 | 87.60 | 77.50 | 78.14 | 80.60 |
| 26.0 | 66.00 | 90.20 | 72.10 | 87.00 | 80.30 | 77.52 | 84.40 |
| 27.0 | 66.40 | 95.20 | 71.80 | 87.30 | 84.40 | 78.91 | 86.70 |
| 28.0 | 67.00 | 91.10 | 72.40 | 88.30 | 87.00 | 77.69 | 86.70 |
| 29.0 | 67.60 | 88.90 | 73.30 | 88.60 | 89.80 | 75.18 | 87.30 |
| 30.0 | 68.60 | 87.30 | 77.10 | 90.50 | 91.10 | 76.56 | 88.30 |
| 31.0 | 69.80 | 87.60 | 80.00 | 95.60 | 91.10 | 80.75 | 89.80 |
| 32.0 | 72.70 | 87.30 | 82.90 | 97.50 | 89.80 | 84.03 | 91.40 |
| 33.0 | 81.00 | 85.40 | 87.30 | 99.00 | 89.80 | 91.32 | 96.50 |
| 34.0 | 85.40 | 84.10 | 90.50 | 99.40 | 89.80 | 97.50 | 97.50 |

| SITE:<br>DATE: | WS-7-2<br>6/10/79 | WS-7-3<br>6/10/79 | WS-7-4<br>6/11/79 | 888D-1<br>5/18/79 | 888D-2<br>5/18/79 | 888D-3<br>5/18/79 | 888D-4<br>5/18/79 |
|---|---|---|---|---|---|---|---|
| STATION | ELEV | ELEV | ELEV | ELEV | ELEV | ELEV | ELEV |
| 1.0 | 85.40 | 86.00 | 93.00 | 85.40 | 88.60 | 92.70 | ****** |
| 2.0 | 86.00 | 86.70 | 92.70 | 87.00 | 88.30 | 94.30 | ****** |
| 3.0 | 86.40 | 87.60 | 93.60 | 88.60 | 95.00 | 89.80 | ****** |
| 4.0 | 87.60 | 87.30 | 94.00 | 89.20 | 90.20 | 89.50 | ****** |
| 5.0 | 85.70 | 90.20 | 93.00 | 91.40 | 88.60 | 89.20 | ****** |
| 6.0 | 86.40 | 91.10 | 89.80 | 89.50 | 87.30 | 87.60 | 90.80 |
| 7.0 | 87.30 | 90.80 | 88.30 | 89.80 | 89.50 | 87.30 | 89.80 |
| 8.0 | 88.60 | 91.80 | 89.80 | 89.50 | 87.60 | 87.00 | 88.90 |
| 9.0 | 86.40 | 90.50 | 88.30 | 88.60 | 88.00 | 88.00 | 89.00 |
| 10.0 | 86.70 | 91.40 | 88.30 | 88.60 | 87.30 | 85.40 | 88.00 |
| 11.0 | 87.90 | 89.20 | 88.60 | 89.20 | 89.20 | 86.40 | 88.00 |
| 12.0 | 87.30 | 89.80 | 88.60 | 89.50 | 89.20 | 86.70 | 87.60 |
| 13.0 | 88.30 | 88.60 | 87.00 | 91.80 | 90.50 | 89.20 | 88.60 |
| 14.0 | 87.60 | 87.60 | 84.40 | 93.00 | 89.20 | 85.10 | 88.60 |
| 15.0 | 86.70 | 86.40 | 83.50 | 93.00 | 89.80 | 85.70 | 86.00 |
| 16.0 | 87.60 | 84.80 | 83.80 | 93.30 | 90.20 | 83.50 | 86.00 |
| 17.0 | 87.60 | 83.80 | 81.60 | 93.70 | 94.30 | 83.50 | 86.00 |
| 18.0 | 89.50 | 83.80 | 82.20 | 93.30 | 93.30 | 82.90 | 85.40 |
| 19.0 | 90.50 | 83.80 | 81.30 | 91.80 | 92.40 | 86.70 | 85.40 |
| 20.0 | 88.60 | 84.40 | 80.00 | 90.80 | 93.70 | 87.00 | 86.00 |
| 21.0 | 89.50 | 89.20 | 81.00 | 90.50 | 93.70 | 86.00 | 85.70 |
| 22.0 | 89.50 | 86.00 | 80.30 | 89.80 | 93.70 | 87.60 | 86.00 |
| 23.0 | 88.30 | 85.70 | 80.30 | 89.80 | 93.00 | 86.00 | 85.40 |
| 24.0 | 87.60 | 85.70 | 77.10 | 92.40 | 93.00 | 85.10 | 84.40 |
| 25.0 | 88.60 | 86.40 | 74.60 | 94.60 | 92.40 | 86.00 | 84.40 |
| 26.0 | 89.20 | 84.40 | 75.60 | 92.40 | 90.20 | 89.50 | 86.70 |
| 27.0 | 89.20 | 84.10 | 72.10 | 92.40 | 93.30 | 85.70 | 85.70 |
| 28.0 | 89.20 | 83.80 | 74.30 | 92.10 | 91.80 | 87.30 | 85.10 |
| 29.0 | 88.90 | 83.80 | 74.30 | 93.00 | 91.10 | 87.60 | 83.50 |
| 30.0 | 90.50 | 83.80 | 74.30 | 93.00 | 92.40 | 91.80 | 84.10 |
| 31.0 | 88.30 | 84.40 | 75.90 | 93.00 | 91.10 | 85.10 | 85.10 |
| 32.0 | 89.50 | 85.40 | 76.50 | 93.00 | 91.80 | 88.00 | 85.40 |
| 33.0 | 88.30 | 85.70 | 77.10 | 93.00 | 92.70 | 88.30 | 87.30 |
| 34.0 | 89.20 | 86.00 | 76.50 | 95.00 | 93.70 | 87.60 | 87.30 |

```
   SITE:  BOWL-1     BOWL-2     BOWL-3     BOWL-4     BOWL-5
   DATE:  7/24/79    7/24/79    7/24/79    7/24/79    7/24/79

STATION    ELEV       ELEV       ELEV       ELEV       ELEV

    1.0    89.80      93.00      84.80      91.10      91.80
    2.0    88.60      91.80      85.10      88.30      91.10
    3.0    88.60      89.20      85.40      84.40      90.80
    4.0    88.60      87.90      86.40      82.50      91.10
    5.0    88.30      86.40      87.30      85.40      92.40
    6.0    86.70      82.90      87.30      82.30      92.10
    7.0    84.80      81.90      86.40      83.20      97.50
    8.0    81.30      80.30      86.00      84.40      94.90
    9.0    82.20      78.10      85.10      86.70      95.20
   10.0    81.60      77.80      84.80      87.90      94.60
   11.0    81.90      76.80      84.80      89.90      91.10
   12.0    82.50      78.10      86.70      92.10      88.60
   13.0    90.20      75.60      85.70      97.80      85.40
   14.0    89.80      76.20      91.40      93.00      82.90
   15.0    88.60      76.20      91.10      93.00      82.50
   16.0    89.80      75.20      90.50      93.30      82.20
   17.0    90.50      75.20      91.10      93.70      81.90
   18.0    92.40      72.40      89.80      93.30      82.90
   19.0    91.10      69.20      90.20      91.30      86.40
   20.0    90.50      73.60      90.20      90.80      88.60
   21.0    91.10      75.90      89.50      90.50      91.80
   22.0    90.20      68.90      87.60      89.30      87.60
   23.0    90.50      68.90      87.00      89.80      87.90
   24.0    89.80      66.40      85.10      92.40      87.60
   25.0    89.80      65.70      83.80      94.60      88.30
   26.0    89.50      68.20      81.90      92.40      89.20
   27.0    87.90      70.80      81.00      92.40      91.10
   28.0    88.60      75.60      80.60      92.10      91.80
   29.0    88.60      77.10      80.00      93.00      91.10
   30.0    86.70      78.70      77.10      93.00      89.80
   31.0    86.00      79.00      79.00      93.00      90.50
   32.0    85.70      80.00      78.40      93.00      90.20
   33.0    86.40      83.80      79.70      93.00      90.20
   34.0    87.60      86.00      82.20      95.00      88.90
```

```
C     THIS PROGRAM PROCESSES EROSION TRANSECT OBSERVATIONS.  IT OUTPUTS
C        FOR EACH SITE BOTH:
C
C             1)  THE GROUND ELEVATIONS AT EACH STATION FOR THE FIRST
C                 TRANSECT
C
C             2)  THE DIFFERENCES IN GROUND ELEVATIONS BETWEEN EACH
C                 SUBSEQUENT TRANSECT AND THE FIRST TRANSECT (ACTUALLY,
C                 THE FIRST OBSERVED GROUND ELEVATION FOR EACH STATION)
C
C     SEPARATE SITES ARE DISTINGUISHED ON THE BASIS OF WATERSHED AND
C        LOCATION.  SEPARATE TRANSECTS AT A SITE ARE DISTINGUISHED BY DATE
C
C     DATA FOR A TRANSECT MUST CONSIST OF A HEADER CARD (SEE NOTE) FOLLOWED
C        BY THE TRANSECT OBSERVATIONS.  THE DATA CARD FORMAT IS:
C
C      CARD
C     COLUMNS  FIELD                        VARIABLE
C
C       1-4      A4    WATERSHED (10A6, WS-1, WS-6, WS-7, BPBC, OR BOWL)
C       5-10    3I2    DATE (MONTH, DAY, YEAR)
C      11-12     A2    DATA TYPE (ALWAYS 'ER' FOR EROSION TRANSECT)
C      13-14     I2    LOCATION (1, 2, ETC.)
C      15-19     5X    --- BLANK ---
C      20-21     I2    STATION (1, 2, ETC.)
C      22-24     3X    --- BLANK ---
C       25       A1    FLAG FOR AN UNOBSERVED STATION ('B' IF UNOBSERVED,
C                          OTHERWISE BLANK)
C      26-30    F5.1   VERTICAL DISTANCE
C      31-80    A50    REMARKS
C
C      (NOTE:  THE HEADER CARD SUPPLIES DATA FOR THE SLOPE OF THE CABLE.  THE
C         THE 'STATION' RECORDED IS THE END STATION OF THE TRANSECT AND THE
C         'VERTICAL DISTANCE' IS THE CABLE RISE/FALL AT THE END STATION
C         FROM STATION 1)
C
C
C
      CHARACTER WS*4(2),B(12),F
      DIMENSION IDATE(3),JDATE(3,12),LO(2),X(35),Y(35,12),E(35,12)
      DIMENSION STA(35),D(35,12)
      J1=0
C
C   READ THE FIRST CARD
C
```

```
    5 READ (5,1001) WS(1),(IDATE(I),I=1,3),LO(1),IH,V
C
C   STORE WATERSHED AND LOCATION, AND INITIALIZE TRANSECT NUMBER
C
   10 WS(2) = WS(1)
      LO(2) = LO(1)
      M=1
      N=IH
C
C   STORE TRANSECT DATE AND COMPUTE CABLE SLOPE
C
   25 DO 28 I=1,3
   28 JDATE(I,M)=IDATE(I)
      S=V/((IH-1.)*15.24)
C
C   READ TRANSECT DATA
C   AND COMPUTE ELEVATIONS AND DIFFERENCES IN ELEVATIONS
C
      DO 30 I=1,N
      READ (5,1002) STA(I),F,Y(I,M)
      X(I)=(STA(I)-1.)*15.24
      IF (F.EQ.'B') THEN DO
            E(I,M)=10000.
            D(I,M)=10000.
         ELSE DO
            E(I,M)=(100.+S*X(I))-Y(I,M)
            DO 29 J=1,M
            IF (E(I,J).LT.9999.) THEN DO
                  D(I,M)=E(I,M)-E(I,J)
                  GO TO 30
               END IF
   29       CONTINUE
         END IF
   30 CONTINUE
C
C   READ HEADER CARD FOR NEXT DATA
C
   31 READ (5,1001,END=38) WS(1),(IDATE(I),I=1,3),LO(1),IH,V
C
C   IF DATA ARE FOR A NEW SITE (DIFFERENT WATERSHED OR LOCATION) GO WRITE
C      OUTPUT FOR THE LAST SITE
C
      IF (WS(1).NE.WS(2)) GO TO 40
      IF (LO(1).NE.LO(2)) GO TO 40
C
C   IF DATA ARE FOR THE SAME SITE (DIFFERENT DATE) INCREMENT TRANSECT
C      NUMBER AND DO PROCESS THE DATA
C
```

```
      DO 32 I=1,3
      IF (IDATE(I).NE.JDATE(I,M)) THEN DO
          M=M+1
          GO TO 25
        END IF
   32 CONTINUE
   38 J1=1
C
C  WRITE THE OUTPUT FOR A SITE (WATERSHED AND LOCATION).  THEN DO
C     PROCESS THE DATA FOR THE NEXT SITE
C
   40 WRITE (6,2001) WS(2), LO(2)
      DO 42 J=1,M
   42 B(J) = ' '
      WRITE (6,2002) ((JDATE(I,J),I=1,3),J=1,M)
      IF (M.GE.2) THEN DO
           WRITE (6,2006) (B(J),J=2,M)
        ELSE DO
           WRITE (6,2003)
        END IF
      WRITE (6,2004)
      DO 50 I=1,N
      IF (M.GE.2) THEN DO
           WRITE (6,2007) STA(I),E(I,1),(D(I,J),J=2,M)
        ELSE DO
           WRITE (6,2005) STA(I),E(I,1)
        END IF
   50 CONTINUE
      IF (J1.EQ.1) STOP
      GO TO 10
 1001 FORMAT (A4,3I2,2X,I2,5X,I2,4X,F5.1)
 1002 FORMAT (19X,F2.0,3X,A1,F5.1)
 2001 FORMAT ('1'//////////' ','WATERSHED:',2X,A4,10X,'LOCATION:',I4//)
 2002 FORMAT (' ',9X,12(I2,'/',I2,'/',I2,2X))
 2003 FORMAT (' ','STATION',4X,'ELEV')
 2004 FORMAT (' ')
 2005 FORMAT (' ',2X,F4.1,4X,F6.2)
 2006 FORMAT (' ','STATION',4X,'ELEV',3X,11(A1,2X,'DIFF',3X))
 2007 FORMAT (' ',2X,F4.1,4X,F6.2,2X,11(2X,F6.2,2X))
      END
```

# APPENDIX K--SLOPE FACTOR CLASSES USED IN LANDSCAPE UNIT ANALYSIS.

< 5% = slopes generally less than 5%
5-50% = slopes generally between 5 to 50%
> 50% = slopes generally greater than 50%

## APPENDIX L--VEGETATION FACTOR CLASSES USED IN LANDSCAPE UNIT ANALYSIS.

(Based on Interagency Browse Map, 1974)

The following is a list of the genera, species and common names of the vegetation factor classes. The shorthand notations are formed by using either the first four letters of the genus (when the species is unknown) and these are all in capital letters, or by combining the first two letters of the genus and the first two letters of the species.

| Symbol | Genus | Species | Common Name |
|---|---|---|---|
| Acco | Acacia | constricta | whitethorn |
| Acgr | Acer | grandidentatum | big-tooth maple |
| Agle | Agave | lecheguilla | lecheguilla |
| ARIS | Aristida | Spp. | three-awn |
| Arte | Arbutus | texana | Texas madrone |
| Atca | Atriplex | canescens | fourwing salt bush |
| Boer | Bouteloua | eriopoda | black grama |
| Cebr | Cercocarpus | breviflorus | mountain mahogany |
| Cegr | Ceanothus | greggii | desert ceanothus |
| Cemo | Cercocarpus | montaum | true mahogany |
| Chdu | Choisya | dumosa | starleaf mexicanorange |
| Coer | Condalia | eriocoides | javelina bush |
| Daar | Dalea | argyraea | silver dalea |
| Dafo | Dalea | formosa | indigo bush |
| Dale | Dasylirion | leiophyllum | smooth sotol |
| EPHE | Ephedra | Spp. | Mormon tea |
| Feru | Fendlera | rupicola | Fendler bush |
| Flce | Flourencia | cernua | tarbush |
| Fosp-1 | Forsellesia | spinescens | spiny greasebush |
| Fosp-2 | Fouquieria | splendens | ocotillo |
| Gawr | Garrya | wrightii | Wright silktassel |
| GUTI | Gutierrezia | Spp. | snakeweed |
| JUNI | Juniperus | Spp. | juniper |
| Jupi | Juniperus | pinchottii | juniper |
| Krgl | Krameria | glandulosa | range ratany |
| Latr | Larrea | tridentata | creosote bush |

| Symbol | Genus | Species | Common Name |
|---|---|---|---|
| Lemi | Leucophyllum | minus | Big Bend silverleaf |
| Lemo | Lepidium | montanum | pepper-grass |
| Matr | Mahonia | trifoliata | algerita |
| Mibi | Mimosa | biuncifera | catclaw mimosa |
| Mosc | Mortonia | scabrella | rough mortonia |
| Mupa | Muhlenbergia | pauciflora | New Mexican muhly |
| Muse | Muhlenbergia | setifolia | curlyleaf muhly |
| Note | Nolina | texana | sacahuista |
| Opim | Opuntia | imbricata | cholla |
| OPPP | Opuntia | Spp. | prickly pear |
| Pain | Parthenium | incanum | mariola |
| PJ | Pinus/<br>Juniperus | Spp.<br>Spp. | pinyon pine/<br>juniper (mixed) |
| PP | Pinus | ponderosa | ponderosa pine |
| Psme | Pseudotsuga | menziesii | Douglas fir |
| QUER | Quercus | Spp. | oak |
| Rhmi | Rhus | microphylla | littleleaf sumac |
| Rhtr | Rhus | trilobata | squawberry |
| RHUS | Rhus | Spp. | sumac |
| Rhvi | Rhus | virens | evergreen sumac |
| ROSA | Rosa | Spp. | rose |
| Spco | Sporobolus | contractus | spike dropseed |
| Spcr | Sporobolus | cryptandrus | sand dropseed |
| Trpu | Tridens | pulchellus | fluffgrass |
| Vist | Viguiera | stenoloba | skeletonleaf goldeneye |
| Yuba | Yucca | baccata | blue yucca |
| Yuel | Yucca | elata | soaptree yucca |
| Yuto | Yucca | torreyi | Torrey yucca |

Community Types

1 = Grassland
3 = Perennial Forb
5 = Mountain Shrub
6 = Conifer
8 = Rock
9 = Pinon-Juniper
10 = Hardwood
11 = Creosote
12 = Mesquite
13 = Fourwing saltbush
16 = Desert Shrub

1-QUER-Note-Dale-Mupa
1-Opim-Prju-Vist-Rhtr
3-GUTI-Matr-Opim-Cebr
3-GUTI-Opim-Rhmi-Dafo
5-Dale-QUER-Cebr-Cegr
5-Dale-QUER-Cebr-Mibi
5-Dale-QUER-Cebr-Gawr
5-Dale-QUER-Cebr-Note
5-QUER-Cebr-Dale-Cegr
5-QUER-Dale-Cebr-Feru
5-QUER-Dale-Cebr-Rhtr
5-Dale-QUER-Cebr-Vist
5-Dale-QUER-Rhtr-Yuel
5-Dale-Vist-QUER-Cebr
5-JUNI-QUER-Arte-Mibi
5-Jupi-QUER-Rhtr-Mibi
5-Cebr-Cegr-Dale-QUER
5-Dale-Note-Cebr-Dafo

5-Mosc-Fosp-2-Cebr-Dafo
5-Cebr-Cegr-QUER-Dale
5-Cebr-Dale-Pain-Cegr
5-Cebr-QUER-Cegr-Dafo
5-Cebr-QUER-Cegr-Dale
5-Dale-Note-Cebr-Mosc
5-Dale-Note-Mosc-Cebr
5-Note-Cebr-Cegr-Mosc
5-Note-Dale-Cebr-Mosc
5-Note-QUER-Cebr-Cegr
5-PJ-Dale-Note-Cebr
5-PJ-Note-Dale-Cebr
5-PP-PJ-QUER-Cebr
5-PJ-QUER-Rhtr-Cebr
5-PJ-PP-QUER-Cebr
5-Note-Cebr-Cegr-Dale
5-Note-Cebr-Cegr-QUER
5-Note-Cebr-Dale-QUER
5-QUER-Cebr-Cegr-Dale
5-QUER-Cebr-Cegr-Note
5-QUER-Cebr-Cemo-Note
5-Dale-QUER-Cegr-Gawr
5-PJ-PP-QUER-Note
5-QUER-Cebr-Rhvi-Dale
5-Dale-Note-QUER-Cebr
5-Note-QUER-Cebr-Dale
5-Note-QUER-Dale-Cebr
5-PJ-QUER-Matr-Opim
5-Dale-Note-Cebr-Cegr
5-Note-Dale-Cebr-Cegr
5-Note-Cebr-Cegr-Muse
5-Note-ROSA-QUER-Cebr
5-QUER-Note-ROSA-Cebr
5-Mosc-Cebr-Pain-Lemi
6-PP-Acgr-Arte-QUER
6-PP-Psme-Acgr-QUER
6-PP-PJ-QUER-Cebr
6-PP-Psme-Acgr-QUER
6-PP-Psme-Acgr-PJ
6-PP-Cebr-Cegr-QUER
6-PP-PJ-Psme-QUER
6-PP-PJ-QUER-Note
8-Rock
9-PJ-Matr-Yuba-Cebr
9-PJ-PP-Note-QUER
9-PJ-PP-QUER-Note
9-PJ-PP-QUER-Cebr
9-PJ-PP-Psme-QUER
9-PJ-QUER-Cegr-Feru
9-PJ-QUER-Cegr-ROSA
10-Acgr-Arte-PP-Cebr
10-Acgr-PP-Psme-Arte
11-Latr-Acco-Pain-Krgl
11-Latr-Acco-Pain-Prju
11-Latr-Acco-Vist-Coer
11-Latr-Mosc-Vist-Coer
11-Latr-Prju-Flce-Krgl
11-Latr-Prju-Flce-Vist
11-Latr-Prju-Krgl-Pain
11-Latr-Prju-Pain-Dafo
11-Latr-Prju-Pain-Drgl
11-Latr-Vist-Prju-Pain
11-Latr-Atca-GUTI-Lemo
11-Latr-Acco-Agle-Vist
11-Latr-Agle-Vist-Pain
11-Latr-Flce-Prju-Krgl
11-Latr-Krgl-Coer-Pain
11-Latr-Pain-Prju-Daar
11-Latr-Vist-Pain-Daar
11-Latr-Krgl-Prju-Vist
11-Latr-Prju-Acco-Pain
11-Latr-Prju-Krgl-Vist
11-Latr-Vist-Pain-Boer
11-Latr-Vist-Pain-Fosp-1
11-Latr-Vist-Pain-OPPP
11-Latr-Prju-Daar-Krgl
12-Prju-GUTI-Atca-Latr
13-Atca-Prju-Spcr-Spco
16-Dale-Mibi-Agle-QUER
16-Jupi-Dale-QUER-Mibi
16-Jupi-QUER-Dale-Mibi
16-Dale-Vist-Pain-Mibi
16-Jupi-QUER-Mibi-Opim
16-Dale-Pain-Vist-Yuel
16-Dale-QUER-Cebr-Cegr
16-Pain-Vist-Dale-QUER
16-Dale-Fosp-2-Mosc-Cebr
16-Dale-Pain-Dafo-Vist
16-Dale-Vist-Fosp-1-Note
16-Dale-Vist-Pain-Agle
16-Dale-Vist-Pain-Dafo
16-Dale-Vist-Pain-Fosp-1
16-Dale-Vist-Pain-Mosc
16-Fosp-1-Agle-Vist-Pain
16-Fosp-1-Dale-Vist-Agle
16-Latr-Coer-Vist-Krgl
16-Pain-Vist-Agle-Fosp-1
16-Pain-Vist-Agle-Latr
16-Vist-Agle-Pain-Fosp-1
16-Vist-Dale-Pain-Agle
16-Vist-Latr-Atca-Prju
16-Vist-Latr-Coer-Krgl
16-Vist-Latr-Pain-Dale
16-Vist-Pain-Agle-Fosp-1
16-Vist-Pain-Dale-Agle
16-Vist-Pain-Dale-Daar
16-Vist-Pain-Dale-Prju
16-Vist-Pain-Latr-Yuel

16-Yuto-Vist-Latr-Coer
16-Agle-OPPP-Vist-Pain
16-Agle-Pain-Vist-Dafo
16-Acco-Fosp-2-Vist-Pain
16-Dale-Fosp-1-Pain-Chdu
16-Dale-Fosp-1-Pain-EPHE
16-Dale-Vist-Pain-Cebr
16-Jupi-Dale-Vist-Mibi
16-Pain-Vist-Trpu-ARIS
16-Dale-Vist-Latr-Pain
16-Pain-Acco-Opim-Vist
16-Acco-Pain-Vist-Muse
16-Vist-Pain-Dale-Cebr

# APPENDIX M--GEOLOGY FACTOR CLASSES* USED IN LANDSCAPE UNIT ANALYSIS

Qr - Rockfall.

Qc - Alluvial material; generally coarse, often partially consolidated.

Qc-fl - Alluvium; coarse to fine material, non-consolidated.

Tl - Thin bedded limestone and/or dolomite.

Ml - Massive or thick bedded limestone and/or dolomite.

SL - Narrow outcrops of alternating sandstone and limestone.

SS - Sandstone.

Sh - Shale.

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*Goolsby, 1974.

## APPENDIX N-- LANDSCAPE UNIT STUDY HOMOGENEITY DATA.

| *Landscape Unit* | Area in Square Miles | Number of *Sites* | Number of *Distinct Units* | Number of *Distinct Units*/ Square Mile | Sites/ Dominant *Distinct Unit* | Number of Dominant *Distinct Units* | Ratio of Dominant *Distinct Units* to Total *Distinct Units* |
|---|---|---|---|---|---|---|---|
| 8 | .113 | 11 | 6 | 53.10 | 1.50 | 2 | .33 |
| 9 | .145 | 3 | 2 | 13.79 | 2.00 | 1 | .50 |
| 28 | .153 | 4 | 3 | 19.61 | 2.00 | 1 | .33 |
| 29 | .154 | 10 | 9 | 58.44 | 1.00 | 2 | .22 |
| 2 | .193 | 6 | 5 | 25.91 | 1.50 | 2 | .40 |
| 23 | .209 | 5 | 4 | 19.14 | 1.00 | 1 | .25 |
| 37 | .220 | 10 | 8 | 36.36 | 1.00 | 3 | .38 |
| 27 | .298 | 26 | 16 | 53.69 | 3.50 | 2 | .13 |
| 38 | .385 | 27 | 20 | 51.95 | 1.00 | 3 | .15 |
| 50 | .425 | 2 | 2 | 4.71 | 1.00 | 1 | .50 |
| 22 | .479 | 22 | 16 | 33.40 | 1.00 | 1 | .06 |
| 42 | .503 | 15 | 11 | 21.87 | 1.67 | 3 | .27 |
| 46 | .514 | 28 | 16 | 31.13 | 3.00 | 3 | .19 |
| 41 | .630 | 20 | 11 | 17.46 | 3.50 | 2 | .18 |
| 32 | .680 | 38 | 17 | 25.00 | 2.00 | 3 | .18 |
| 58 | .683 | 47 | 19 | 27.82 | 4.00 | 3 | .16 |
| 47 | .753 | 29 | 10 | 13.28 | 4.50 | 2 | .20 |
| 21 | .832 | 10 | 6 | 7.21 | 2.00 | 1 | .17 |
| 13 | .999 | 51 | 28 | 28.03 | 4.00 | 3 | .11 |
| 53 | 1.007 | 47 | 21 | 20.85 | 4.00 | 4 | .19 |
| 40 | 1.026 | 29 | 13 | 12.67 | 5.50 | 2 | .15 |
| 43 | 1.127 | 78 | 27 | 23.96 | 6.00 | 3 | .11 |
| 30 | 1.220 | 6 | 5 | 4.10 | 1.00 | 1 | .20 |
| 44 | 1.445 | 55 | 23 | 15.92 | 7.00 | 2 | .09 |
| 11 | 1.525 | 13 | 7 | 4.59 | 6.00 | 1 | .14 |
| 95 | 1.544 | 16 | 5 | 3.24 | 5.00 | 1 | .20 |
| 15 | 1.617 | 98 | 28 | 17.32 | 12.00 | 2 | .07 |
| 54 | 1.620 | 105 | 49 | 30.25 | 4.57 | 7 | .14 |
| 17 | 1.849 | 79 | 32 | 17.31 | 4.00 | 3 | .09 |
| 6 | 1.992 | 52 | 24 | 12.05 | 1.00 | 1 | .04 |
| 4 | 2.090 | 40 | 18 | 8.61 | 4.00 | 2 | .11 |
| 5 | 2.263 | 160 | 54 | 23.86 | 6.71 | 7 | .13 |
| 34 | 2.268 | 55 | 21 | 9.26 | 2.00 | 1 | .05 |
| 39 | 2.377 | 152 | 33 | 13.88 | 13.20 | 5 | .15 |
| 45 | 2.404 | 79 | 23 | 9.57 | 4.50 | 2 | .09 |
| 14 | 3.129 | 94 | 26 | 8.31 | 11.00 | 2 | .08 |
| 52 | 3.469 | 77 | 46 | 13.26 | 1.33 | 6 | .13 |
| 51 | 3.514 | 105 | 50 | 14.23 | 5.00 | 5 | .10 |
| 57 | 3.759 | 132 | 74 | 19.69 | 2.00 | 10 | .14 |
| 36 | 4.007 | 257 | 61 | 15.22 | 12.33 | 6 | .10 |
| 20 | 5.746 | 120 | 44 | 7.66 | 8.50 | 2 | .05 |
| 10 | 6.692 | 60 | 31 | 4.63 | 3.00 | 2 | .07 |
| 3 | 8.023 | 240 | 60 | 7.47 | 3.20 | 5 | .08 |
| 16 | 12.394 | 724 | 108 | 8.71 | 24.86 | 7 | .07 |
| 7 | 16.112 | 304 | 150 | 9.31 | 3.33 | 9 | .06 |
| 12 | 17.369 | 367 | 243 | 13.99 | 9.63 | 30 | .12 |

## APPENDIX O--HOTELLING AND PABST'S TEST FOR RANK-ORDER CORRELATION.

$$r_s = 1 - \frac{6 \sum_{i=1}^{n} d_i^2}{n(n^2 - 1)}$$

$r_s$ - Spearman's rank-difference correlation coefficient

$d_i$ - the difference between the *X*-rank and the *Y*-rank for the *i*th unit

## DISCUSSION

This is a test for examining the independence of two sets of measurements made on *n* randomly drawn units. Each of the measurements of each set is replaced by its rank order, the smallest receiving a rank of 1 and the highest, the rank of *n*. In the event of ties, a middle rank is chosen. For example, if two measurements were tied for the 15th rank, each would be assigned 15.5 and the next higher measurements would receive a rank of 17. If there are three or more measurements tied, the median rank is assigned: e.g., a three-way tie for the 18th rank would result in 19 being assigned to all three and the next higher measurement would be ranked 21.

One of the sets (X) is then arbitrarily arranged in order of increasing ranks. The "obtained data will be uniquely identified by the corresponding linear arrangement of the *n* associated *Y*-ranks." The *Y*-ranks are then subtracted from the *X*-ranks to obtain the rank difference. This quantity is squared and all are then summed. "If $H_0$ is false, i.e., if the *X*- and *Y*-variates are correlated, then the obtained values of $r_s$ . . . should be excessively likely to fall at one of the tails of their null distributions." (Bradley, 1968)

The critical values of *n* = 46 are: $-0.50 \geq r_s \geq 0.50$, with $\alpha = 0.0005$.

| *Landscape Unit* | *Landscape Unit* Rank (by area) | *Distinct Units* per Unit Area Rank | Rank Difference $d_i$ | Rank Difference Squared $d_i^2$ |
|---|---|---|---|---|
| 8 | 1 | 44 | -43 | 1849 |
| 9 | 2 | 19 | -17 | 289 |
| 28 | 3 | 29 | -26 | 676 |
| 29 | 4 | 46 | -42 | 1764 |
| 2 | 5 | 36 | -31 | 961 |
| 23 | 6 | 28 | -22 | 484 |
| 37 | 7 | 42 | -35 | 1225 |
| 27 | 8 | 45 | -37 | 1369 |
| 38 | 9 | 43 | -34 | 1156 |
| 50 | 10 | 5 | 5 | 25 |
| 22 | 11 | 41 | -30 | 900 |
| 42 | 12 | 32 | -20 | 400 |
| 46 | 13 | 40 | -27 | 729 |
| 41 | 14 | 27 | -13 | 169 |
| 32 | 15 | 35 | -20 | 400 |
| 58 | 16 | 37 | -21 | 441 |
| 47 | 17 | 18 | -1 | 1 |
| 21 | 18 | 6 | 12 | 144 |
| 13 | 19 | 38 | -19 | 361 |
| 53 | 20 | 31 | -11 | 121 |
| 40 | 21 | 16 | 5 | 25 |
| 43 | 22 | 34 | -12 | 144 |
| 30 | 23 | 2 | 21 | 441 |
| 44 | 24 | 24 | 0 | 0 |
| 11 | 25 | 3 | 22 | 484 |
| 95 | 26 | 1 | 25 | 625 |
| 15 | 27 | 26 | 1 | 1 |
| 54 | 28 | 39 | -11 | 121 |
| 17 | 29 | 25 | 4 | 16 |
| 6 | 30 | 15 | 15 | 225 |
| 4 | 31 | 10 | 21 | 441 |
| 5 | 32 | 33 | -1 | 1 |
| 34 | 33 | 12 | 21 | 441 |
| 39 | 34 | 20 | 14 | 196 |
| 45 | 35 | 14 | 21 | 441 |
| 14 | 36 | 9 | 27 | 729 |
| 52 | 37 | 17 | 20 | 400 |
| 51 | 38 | 22 | 16 | 256 |
| 57 | 39 | 30 | 9 | 81 |
| 36 | 40 | 23 | 17 | 289 |
| 20 | 41 | 8 | 33 | 1089 |
| 10 | 42 | 4 | 38 | 1444 |
| 3 | 43 | 7 | 36 | 1296 |
| 16 | 44 | 11 | 33 | 1089 |
| 7 | 45 | 13 | 32 | 1024 |
| 12 | 46 | 21 | 25 | 625 |

$$\sum_{i=1}^{n} d_i^2 = 25388$$

$$r_s = 1 - \frac{6\ (25388)}{97290}$$

$$= 1 - 1.57$$

$$= -0.57$$

| *Landscape Unit* | *Landscape Unit* Rank (by area) | *Sites* per Dominant *Distinct Unit* Rank | Rank Difference $d_i$ | Rank Difference Squared $d_i^2$ |
|---|---|---|---|---|
| 8 | 1 | 10.5 | -9.5 | 90.25 |
| 9 | 2 | 15 | -13 | 169 |
| 28 | 3 | 15 | -12 | 144 |
| 29 | 4 | 10.5 | -6.5 | 42.25 |
| 2 | 5 | 4.5 | 0.5 | 0.25 |
| 23 | 6 | 4.5 | 1.5 | 2.25 |
| 37 | 7 | 4.5 | 2.5 | 6.25 |
| 27 | 8 | 23.5 | -15.5 | 240.25 |
| 38 | 9 | 4.5 | 4.5 | 20.25 |
| 50 | 10 | 4.5 | 5.5 | 30.25 |
| 22 | 11 | 4.5 | 6.5 | 42.25 |
| 42 | 12 | 12 | 0 | 0 |
| 46 | 13 | 18 | -5 | 25 |
| 41 | 14 | 23.5 | -9.5 | 90.25 |
| 32 | 15 | 18 | -3 | 9 |
| 58 | 16 | 27 | -11 | 121 |
| 47 | 17 | 30.5 | -13.5 | 182.25 |
| 21 | 18 | 15 | 3 | 9 |
| 13 | 19 | 27 | -8 | 64 |
| 53 | 20 | 27 | -7 | 49 |
| 40 | 21 | 35 | -14 | 196 |
| 43 | 22 | 36.5 | -14.5 | 210.25 |
| 30 | 23 | 4.5 | 18.5 | 342.25 |
| 44 | 24 | 39 | -15 | 225 |
| 11 | 25 | 36.5 | -11.5 | 132.25 |
| 95 | 26 | 33.5 | -7.5 | 56.25 |
| 15 | 27 | 43 | -16 | 256 |
| 54 | 28 | 32 | -4 | 16 |
| 17 | 29 | 27 | 2 | 4 |
| 6 | 30 | 4.5 | 25.5 | 650.25 |
| 4 | 31 | 27 | 4 | 16 |
| 5 | 32 | 38 | -6 | 36 |
| 34 | 33 | 15 | 18 | 324 |
| 39 | 34 | 45 | -11 | 121 |
| 45 | 35 | 30.5 | 4.5 | 20.25 |
| 14 | 36 | 42 | -6 | 36 |
| 52 | 37 | 9 | 28 | 784 |
| 51 | 38 | 33.5 | 4.5 | 20.25 |
| 57 | 39 | 15 | 24 | 576 |
| 36 | 40 | 44 | -4 | 16 |
| 20 | 41 | 40 | 1 | 1 |
| 10 | 42 | 18 | 24 | 576 |
| 3 | 43 | 21 | 22 | 484 |
| 16 | 44 | 46 | -2 | 4 |
| 7 | 45 | 22 | 23 | 529 |
| 12 | 46 | 41 | 5 | 25 |

$$\sum_{i=1}^{n} d_i^2 = 6993.5$$

$$r_s = 1 - \frac{6\ (6993.5)}{97290}$$

$$= 1 - 0.43$$

$$= 0.57$$

| *Landscape Unit* | *Landscape Unit* Rank (by area) | Number of Dominant *Distinct Units* per Total Number of *Distinct Units* Rank | Rank Difference $d_i$ | Rank Difference Squared $d_i^2$ |
|---|---|---|---|---|
| 8 | 1 | 41.5 | -40.5 | 1640.25 |
| 9 | 2 | 45.5 | -43.5 | 1892.25 |
| 28 | 3 | 41.5 | -38.5 | 1482.25 |
| 29 | 4 | 38 | -34 | 1156 |
| 2 | 5 | 44 | -39 | 1521 |
| 23 | 6 | 39 | -33 | 1089 |
| 37 | 7 | 43 | -36 | 1296 |
| 27 | 8 | 21 | -13 | 169 |
| 38 | 9 | 27 | -18 | 324 |
| 50 | 10 | 45.5 | -35.5 | 1260.25 |
| 22 | 11 | 4.5 | 6.5 | 42.25 |
| 42 | 12 | 40 | -28 | 784 |
| 46 | 13 | 33.5 | -20.5 | 420.25 |
| 41 | 14 | 31.5 | -17.5 | 306.25 |
| 32 | 15 | 31.5 | -16.5 | 272.25 |
| 58 | 16 | 29 | -13 | 169 |
| 47 | 17 | 36 | -19 | 361 |
| 21 | 18 | 30 | -12 | 144 |
| 13 | 19 | 17 | 2 | 4 |
| 53 | 20 | 33.5 | -13.5 | 182.25 |
| 40 | 21 | 27 | -6 | 36 |
| 43 | 22 | 17 | 5 | 25 |
| 30 | 23 | 36 | -13 | 169 |
| 44 | 24 | 12 | 12 | 144 |
| 11 | 25 | 24 | 1 | 1 |
| 95 | 26 | 36 | -10 | 100 |
| 15 | 27 | 7 | 20 | 400 |
| 54 | 28 | 24 | 4 | 16 |
| 17 | 29 | 12 | 17 | 289 |
| 6 | 30 | 1 | 29 | 841 |
| 4 | 31 | 17 | 14 | 196 |
| 5 | 32 | 21 | 11 | 121 |
| 34 | 33 | 2.5 | 30.5 | 930.25 |
| 39 | 34 | 27 | 7 | 49 |
| 45 | 35 | 12 | 23 | 529 |
| 14 | 36 | 9.5 | 26.5 | 702.25 |
| 52 | 37 | 21 | 16 | 256 |
| 51 | 38 | 14.5 | 23.5 | 552.25 |
| 57 | 39 | 24 | 15 | 225 |
| 36 | 40 | 14.5 | 25.5 | 650.25 |
| 20 | 41 | 2.5 | 38.5 | 1482.25 |
| 10 | 42 | 7 | 35 | 1225 |
| 3 | 43 | 9.5 | 33.5 | 1122.25 |
| 16 | 44 | 7 | 37 | 1369 |
| 7 | 45 | 4.5 | 40.5 | 1640.25 |
| 12 | 46 | 19 | 27 | 729 |

$$\sum_{i=1}^{n} d_i^2 = 28315$$

$$r_s = 1 - \frac{6\ (28315)}{97290}$$

$$= 1 - 1.75$$

$$= -0.75$$